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# NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

## TECHNICAL NOTE

No. 1834

### THE INFLUENCE OF BLADE-WIDTH DISTRIBUTION ON PROPELLER CHARACTERISTICS

By Elliott G. Reid

Stanford University

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SUMMARY

Combined force and wake survey tests on three-blade model propellers have been made in the Guggenheim Aeronautic Laboratory of Stanford University to determine the effects of blade-width distribution upon constant-speed efficiency characteristics.

The blades of the various models differed widely in plan form but all incorporated the same pitch distribution and were of such widths as to make their activity factors equal; as a result, all the models exhibited substantially identical power-absorption capacities at equal pitch settings.

The force test results show that the envelope efficiency curves for the several types of blades differ appreciably only at advance ratios less than 1.0 and greater than 3.0; in those ranges the envelope efficiencies of the best of the tapered blades are slightly inferior to those of blades characterized by approximate uniformity of width. On the other hand, the constant-speed efficiency curves ( $\eta$  vs.  $V/nD$  for fixed values of  $C_P$ ) diverge substantially as the advance ratios are reduced below the values at which the maximum efficiencies occur. At these reduced advance ratios, and at all values of power coefficient equal to or greater than 0.1, blades tapered from broad roots to narrow tips attained greater efficiencies than did those of relatively uniform width. However, at power coefficients appreciably less than 0.1, the untapered blades were found to be somewhat more efficient than tapered ones at all advance ratios. Similar, and only slightly smaller, differences of constant-speed efficiency were found when the continuously tapered blades were replaced by a compromise type in which the root width was reduced to a practically acceptable value.

Analysis of the thrust and torque grading curves indicates that the more efficient operation of the tapered blades at reduced advance ratios is the result of a redistribution of loading which augments the proportion of the total power input absorbed by the inboard elements which continue to function efficiently as the outboard elements approach and exceed their stalling angles. While the specific cause of the inferiority of the tapered blades at small power coefficients is not entirely clear, it is apparent that this inferiority might be reduced -

if not eliminated - by diminishing the thickness of the inboard sections of the tapered blades which was unnecessarily great as a result of the use of geometrically similar profiles at equal radii in models of different plan forms.

An incidental result of fundamental significance concerns the theory of blade-element independence. Despite its previous apparent verification by the results of experiments in which only the pitch distribution was varied, the theory is definitely not substantiated by the wake survey data obtained with the present models of various plan forms.

Correlation of results from this investigation with those of preceding studies indicates that the incorporation of highly cambered profiles in propellor blades is generally undesirable and that the so-called "envelope" pitch distribution does not possess the merits predicted by extrapolation of previous test results.

#### INTRODUCTION

The origin of the present investigation may be of more than usual interest because it illustrates so clearly the pervasive tendency of accepted practices to infiltrate a field of knowledge and, as the result of long usage, to achieve the undeserved status of features of scientifically proven merit.

In 1943, the writer called attention to certain marked differences between the constant-speed efficiency curves for two model propellers which, in his opinion, differed significantly only in the plan forms of their blades. The minor influence generally ascribed to this design parameter led to vigorous controversy over the chief cause of the differences but this, in the end, proved inconclusive. However, the discussion did serve to establish the rather startling fact that, after 40 years of successful screw propulsion of airplanes, the effects of blade-width distribution upon propeller characteristics remained substantially unknown. Thus, both the plan forms in general use and the basic concept of width distribution as an unimportant design factor were seen to have gained unwarranted acceptance.

Recognition of this lack of fundamental information, and of the possibility of improvement by means hitherto unexplored, led to the study described in this report. This investigation was conducted under the sponsorship and with the financial assistance of the National Advisory Committee for Aeronautics.

As existing information on the subject of plan-form influence is largely that derived from tests of fixed-pitch models (references 1 to 8) and is further complicated by variation of the activity factor in

all cases, the present exploratory program had to be based, in the main, upon such inferences as could be drawn from the single aforementioned comparison. In that case, two model propellers characterized by practically identical activity factors and barely distinguishable efficiency envelopes exhibited marked differences of constant-speed efficiency ( $\eta$  at  $C_p = \text{Constant}$ ) at reduced advance ratios. The one which developed the greater efficiencies in this range had blades in which the width of the intermediate portion was substantially greater than that of either root or tip, whereas the width of the inferior blades was much more nearly uniform. Upon the basis of these few facts, the models described in the present paper were designed to enable exploration of the effects of continuous taper from root to tip and those of taper from an intermediate station toward both extremities.

## SYMBOLS

A	disc area, square feet ( $\pi D^2/4$ )
D	diameter, feet
R	tip radius, feet
r	radius of element, feet (See also definition of a.)
x	radius ratio ( $r/R$ )
b	width (chord) of element, feet
h	maximum thickness of element, feet
$\beta$	pitch angle of element, degrees (reference - chord)
$\beta'$	pitch angle of element, degrees (reference - lift axis)
$\beta_T'$	pitch angle of tip element, degrees
$\psi$	angle of yaw, degrees
V	velocity, feet per second
$V_s$	slipstream velocity, feet per second
u	axial component of $V_s$
w	tangential component of $V_s$
a	coefficient of induced axial velocity (Note: $1 + a = r$ .)

$\rho$  air density, slugs per cubic foot  
 $\sigma$  relative air density  $(\rho/\rho_0)$   
 S.P. static plate pressure difference, pounds per square foot  
 $(q = 1.046 \text{ S.P.})$

$$q = \rho V^2/2 \quad q_w = \rho w^2/2 \quad E = q_w/q$$

$E_1, E_2$  successive approximations of  $E$

$n$  rotative speed, revolutions per second  
 $V/nD$  advance ratio  $(V/nD = J)$

$p_0$  static pressure at upstream face, pounds per square foot  
 $p_1$  static pressure at downstream face, pounds per square foot  
 $\Delta p$  increase of static pressure, pounds per square foot  $(p_1 - p_0)$   
 $p_{to}$  total pressure in undisturbed stream, pounds per square foot  
 $p_{tl}$  total pressure at downstream face, pounds per square foot  
 $\Delta p_t$  increase of total pressure, pounds per square foot  $(p_{tl} - p_{to})$

$$P_{T0} = p_{to}/q \quad P_{T1} = p_{tl}/q \quad \Delta P_T = P_{T1} - P_{T0} \quad \Delta P = \Delta P_T - E$$

$\Delta P_1, \Delta P_2$  successive approximations of  $\Delta P$

$p_u$  total pressure on upstream<sup>1</sup> tube of yaw head, pounds per square foot

$p_d$  total pressure on downstream<sup>1</sup> tube of yaw head, pounds per square foot

$p_y$  yaw-head pressure difference, pounds per square foot  $(p_u - p_d)$

$$P_U = p_u/q \quad P_D = p_d/q \quad P_{YO} = p_y/q \quad P_Y = P_{YO} + \Delta P_Y$$

---

<sup>1</sup>With reference to tangential velocity normally imparted to slipstream.

$\Delta P_Y$	value of $-P_{Y0}$ in undisturbed stream
$K$	yaw-head constant ( $K = P_Y / \sin 2 \psi$ )
$T$	thrust, pounds
$Q$	torque, pound-feet
$P$	power input, foot-pounds per second
$C_{TO}$	integrated thrust coefficient <sup>2</sup> $\left( C_{TO} = \int_{0.15}^{1.0} (dC_T/dx) dx \right)$
$\Delta C_T$	spinner thrust coefficient (Absolute values; spinner thrust is actually negative.)
$C_T$	thrust coefficient $(T/\rho n^2 D^4)$ ; $(C_T = C_{TO} - \Delta C_T)$
$C_Q$	torque coefficient <sup>2</sup> $(Q/\rho n^2 D^5)$ ; $\left( C_Q = \int_{0.15}^{1.0} (dC_Q/dx) dx \right)$
$C_P$	power coefficient $(P/\rho n^3 D^5)$ ; $(C_P = 2\pi C_Q)$
$\eta$	efficiency $(C_T V / C_P n D)$
$dT$	thrust of all elements at radius $r$ , pounds
$dQ$	torque of all elements at radius $r$ , pound-feet
$\eta_e$	efficiency of element
A.F.	activity factor $\left( AF = 6250 \int_{0.15}^{1.0} \left( \frac{b}{D} \right) \left( \frac{r}{R} \right)^3 d\left( \frac{r}{R} \right) \right)$

<sup>2</sup>Upper limit nominal; integration extended to include entire area enclosed by curve.

## MODELS

Seven 3-blade, adjustable-pitch, metal, model propellers of 2.80-foot diameter were designed and constructed for use in this investigation. Of these, six (models 1 to 6) differ only in plan form, that is, they have identical distributions of pitch and their profiles at equal radii are geometrically similar. Because the profiles and pitch distribution incorporated in these models differ, somewhat, from any previously tested under similar conditions, the "transition type," model 7, which differs from model 6 only in profiles, was added to the series to enable correlation of the present test results with those of previous investigations. Examples of all six plan forms are illustrated by photograph (fig. 1).

The radial distributions of blade width for models 1 to 5 were obtained by systematic distortion of one quadrant of an ellipse.<sup>3</sup> The "basic" blade-width curves<sup>4</sup> of figure 2 are defined by the equation<sup>5</sup>

$$(b/D)_o = \sin^{s\theta} \cos^{c\theta} \quad (1)$$

in which  $\theta = \cos^{-1}(r/R)$ . The various models are characterized by the following values of the exponents  $s$  and  $c$ :

Model	1	2	3	4	5
$s$	5/4	3/4	1/4	5/4	5/4
$c$	0	0	0	1/4	1/2

The actual blade-width curves for models 1 to 5 (fig. 3) were obtained by multiplying the ordinates of each of the basic width curves by the constant required to make the corresponding activity factor equal to 92.<sup>6</sup>, which is the value of that quantity for the "conventional" plan form<sup>6</sup> incorporated in model 6. The activity factors were equalized with the object of insuring, insofar as is possible by the use of a simple design criterion, equal absorption of power by the several models under comparable conditions of operation. The arbitrary distribution of width in model 6 is also illustrated by figure 3.

<sup>3</sup>The ellipse was selected as a basis only because it can be so conveniently modified to yield taper characteristics of the desired variety.

<sup>4</sup>Unequal scales have been used to enhance the resemblance between the basic and actual width curves.

<sup>5</sup>When  $s = 1$  and  $c = 0$ , (1) becomes the equation of a circle but the introduction of an arbitrary constant - to obtain normal width ratios - transforms it into that of an ellipse.

<sup>6</sup>Also used for model 7; previously incorporated in the members of the U- and E-series of references 9 and 10.

With reference to the various width distributions, the following features are noteworthy:

- (a) The severity of continuous taper diminishes progressively from model 1 to model 3.
- (b) Model 3 is of more nearly uniform width and has a broader tip than the "conventional" model 6. (Note, however, that the outboard portion of model 6 is wider than the shank.)
- (c) The tips of models 1, 4, and 5 are more severely tapered than those of the other models and differences between the width distributions for these three are largely confined to the inner portions of the blades.

The thickness and pitch distributions for models 1 to 6 are defined by figure 4; NACA 16-series profiles of 0.7 design lift coefficient have been incorporated throughout the lengths of these blades.

Model 7 is distinguished from model 6 only by differences between their profiles. Those of model 7 are identical with the ones used for the U- and E-series blades of references 9 and 10, that is, 16-series tips and roots are separated by a central portion in which Clark Y profiles are incorporated. The thickness- and pitch-distribution curves for model 7 will be found in figure 4.

The pitch distribution for all seven models is the so-called "envelope" type; the equation of the twist curve is

$$\beta' - \beta_T' = \cot^{-1} \sqrt{x} - \tan^{-1} \sqrt{x} \quad (2)$$

The curve so defined is the envelope of the twist curves ( $\beta' - \beta_T'$  against  $x$ ) for all propellers of uniform design pitch.

During tests, the hubs of all models were enclosed within a spinner of the form shown in figure 5 and the apertures for the blades were sealed by closely fitted masks.

#### APPARATUS AND TECHNIQUE

The experimental work, which was conducted in the 7.5-foot wind tunnel of Stanford's Guggenheim Aeronautic Laboratory (reference 11), consisted in making routine force tests and complete surveys of the wakes of all seven models, each of which was tested, successively, at

six pitch angles. The force and slipstream pressure observations were made simultaneously.

Models were driven by the customary propeller dynamometer (reference 11), which was improved, prior to the present tests, by some refinement of its shrouding and by the substitution of automatic electric balances for the manually operated ones previously used for thrust and torque measurement.

The character and general arrangement of the wake survey apparatus is illustrated by figures 5 to 8. The combined total-head and yaw tubes were installed in 3 radial rows of 10 tubes each; 1 row extended vertically above the propeller shaft while the other 2 were symmetrically arranged at angles of  $45^\circ$  below the horizontal. Corresponding tubes of each row were located at equal radial distances from the shaft axis and the tips of all tubes were  $0.07D$  behind the plane of the blade axes.

Recognition of the extreme sensitivity of survey-determined thrust and torque to nonuniformity of the dynamic and total pressures of the undisturbed stream<sup>7</sup> indicated the desirability of carrying the refinement of free-stream characteristics to the limit of practicability and then minimizing the errors due to residual nonuniformity by averaging multiple observations of the slipstream pressures at each radius.

Readjustment of the density of return-passage screens and installation of a boundary-layer-removal device at the tip of the entrance deflector resulted in small, but worth while, improvements in velocity and total-head distributions at the test section. The maximum variation of the circumferential averages of the total heads at eight points on each of a series of concentric circles having radii of 4.5 to 22.5 inches was reduced to  $\pm 0.006q$ , while corresponding variation of the dynamic pressure was even smaller outside the 8.5-inch radius which appeared to be the limit of spinner influence.<sup>8</sup> Three banks of yaw heads were then installed and interconnected as explained in the following paragraph; this arrangement enabled direct recording of the averages of the slipstream pressures at corresponding points of three radial lines. The banks were spaced at angular intervals of  $135^\circ$ ,  $90^\circ$ , and  $135^\circ$  to preclude simultaneous impingement of the wakes of two or more blades upon the survey instruments.

Ninety small copper tubes (0.090 in., O.D.; 0.030 in., I.D.) transmitted the pressures from the yaw heads to a multiple manifold (fig. 7) which consisted of thirty four-way connections. The three tubes

<sup>7</sup>Discussed in reference 10.

<sup>8</sup>Between radii of 8.5 and 4.5 inches,  $q$  increases by 2.5 percent.

communicating with corresponding elements of the three yaw heads at each radius were interconnected at the manifold and the average pressure was transmitted to a single column of the recording manometer by a tube attached to the remaining branch of each four-way connection.

The yaw- and total-head tubes used in these tests are, themselves, the results of somewhat extensive research. In reference 10, the failure of conventional shielded total-head tubes to function satisfactorily behind a stalled model was tentatively ascribed, after stroboscopic observation of the behavior of wool tufts, to periodic interruption of continuous flow through the shields due to the occurrence of very large angles of yaw in the highly turbulent wakes of the blades. It was also suspected that the range of angle of yaw within which such tubes give reliable indications of total head might be appreciably reduced by fluctuations of velocity, even in the absence of directional variations. The task of developing a total-head tube substantially free of these defects throughout the range of angle of yaw between  $-20^\circ$  and  $90^\circ$  was therefore undertaken and, at the same time, improvement of the calibration characteristics of the previously used type of yaw head was sought. The most significant results of this auxiliary study are summarized as follows.

Tests of a shielded total-head tube of conventional type showed that, in flow pulsating at a frequency comparable to that of the passage of blades during model tests, the range of  $\psi$  within which  $p_t/q = 1.0$  was reduced from the steady-flow value of  $\pm 60^\circ$  to one of  $\pm 50^\circ$ . However, the effect of such pulsation upon the values of  $\psi$  at which  $p_t/q = 0$  was found to be practically negligible.

No material improvement was effected by altering either the size or the length-diameter ratio of a shield of conventional venturi form. On the other hand, the use of a highly cambered profile for the venturi wall (type B, fig. 9) was found to be definitely beneficial.

Much more substantial improvements were effected by the use of asymmetric shields which, although unsuitable for some purposes, are entirely satisfactory for propeller wake surveys because the local angles of yaw which occur within the positive range of total thrust attain large values of only one sense.<sup>9</sup> The first unsymmetric types investigated were made from conventional venturi shields by cutting off their ends obliquely and then restoring smoothness of the internal contours by hand-filing. The improved characteristics obtained by truncating both ends at angles of  $70^\circ$  with respect to the axis are shown in figure 9 (type C), but the mechanical difficulty of accurately duplicating such an asymmetric shield discouraged its adoption. It was recognized that

<sup>9</sup>True everywhere except at the boundary of the slipstream and erroneous there only when the tip elements produce considerable negative thrust.

substantially identical characteristics might be obtained by oblique orientation of a symmetrically shielded total-head element with reference to the axis of the yaw head but the probability of consequent adverse effects upon the calibration of the yaw head itself made this alternative seem unattractive.

A simultaneous solution of the problems of interference and reproducibility was finally found in the half-venturi shield which is designated as "type D" in figure 9. Such shields are readily duplicated by using formed reamers to shape complete venturis which are then milled off to their planes of symmetry, and they exercise no appreciable influence on the direction of flow at the tips of the yaw tubes. Moreover, they were found to possess the best calibration characteristics of any type tested. The curve for type D shown in figure 9 is applicable to an isolated total-head tube of this form, but the relatively slight adverse effects of combination with the yaw head may be seen in figure 10 where the calibration curves for the complete prototype instrument are reproduced. The introduction of pitch angles as great as  $\pm 10^\circ$  had no perceptible effect upon the total pressure calibration, but, at negative angles of yaw, the device is somewhat sensitive to changes of location of the shield with respect to the total-pressure orifice.

Improvement upon the calibration characteristics of the yaw heads used in previous wake surveys (reference 10) was sought through a further study of tip form. The effects of bevel angle, diameter of bore, and width of flat at the mouth of the bore were investigated rather thoroughly and, although no spectacular improvement was effected, some benefits were obtained by changes of bevel and bore. Details of the form of tip incorporated in the present yaw heads are given in figure 10 where the corresponding calibration curve is compared with that of the older type.

As the result of unsatisfactory experience with yaw heads which consisted, essentially, of three small steel tubes soldered together, the much more substantial design shown in figure 10 was adopted for this investigation. The photograph (fig. 11) illustrates how the separately fabricated tips and shield are accurately located by a jig-machined, solid brass body into which they and the three pressure lines are sweated. The body is lightly pressed into the stout steel tube stem and secured by a set screw. A shoulder on the stem rests upon a spot-faced surface at the mouth of a hole reamed through the walls of the supporting tube to insure correct location of the assembly; collapse of the slotted end of the stem under pressure of the anchoring nut is prevented by a plug. Although this construction involved considerable precision work, it proved eminently satisfactory; no disturbance of the delicate pressure balance of the yaw heads was detected during the entire investigation.

The technique of recording the wake survey data consisted in photographing the multiple manometer with a 35-millimeter camera. In addition to total- and yaw-head pressures, a pressure difference of precisely known magnitude and one proportional to the dynamic pressure

of the wind stream were imposed upon manometer columns and recorded in each photograph so that the records would be self-sufficient, that is, entirely determinate without reference to the manometer liquid density. Improvements in illumination and the use of a fast lens permitted recording on Microfile film at 1/50-second exposure with f 2.8 aperture; negatives characterized by high contrast and sharp meniscus definition were thus obtained. Such records warranted further refinement of the projection-measuring equipment described in reference 10; a micrometer screw, equipped with direct-reading, geared counters was substituted for the previously used vernier-read scales. The over-all result of these improvements was to enable the scaling of pressure records to be repeated with an accuracy of  $\pm 0.001q$  when  $q = 10$  pounds per square foot and with inversely proportionate accuracy at smaller values of  $q$ .

Perceptible interference effects due to the presence of the wake survey apparatus were shown to be nonexistent by force tests made before and after its installation.

#### TEST PROGRAM

In accordance with regular Stanford practice, the model propellers of this series were tested at fixed rotative speeds and the advance ratio was varied by changing the airspeed. Each model was tested at the following pitch settings and rotative speeds:

$\beta^{10}$ (deg)	12	19	27	37	48	60
Speed, rpm	2100	2100	1740	1470	1056	744

The airspeeds ranged from approximately 90 miles per hour down to the lowest values at which significant force readings could be obtained. Since the maximum Mach number attained by the tip elements was approximately 0.3, the effects of compressibility upon the test results are considered to be negligible.

As has been customary in the past, two complete force tests (consisting of 10 to 24 sets of observations) were made at each blade setting and the advance ratios utilized in one test were staggered with reference to those of the other. Wake survey data were recorded simultaneously with each observation of force data during one of each pair of tests. The number of manometer records so made was unnecessarily large, but it was thus insured that the limited number required to illustrate significant variations of blade loading would be available for reduction to numerical and graphical forms. These records were

<sup>10</sup> Nominal blade angles at 0.75R; reference, chord.

selected by reference to the force test curves; their number varied from 6, when the pitch setting was  $12^\circ$ , to 14, when  $\beta = 60^\circ$ .

#### REDUCTION OF DATA

The force test data have been reduced to the usual nondimensional forms

$$V/nD$$

$$C_P = P/\rho n^3 D^5$$

$$C_T = T/\rho n^2 D^4$$

and

$$\eta = (C_T/C_P) (V/nD)$$

In their evaluation, the only corrections applied were those required to adjust the measured thrusts to the values which would have prevailed had the pressure on the back of the spinner been exactly equal to the static pressure of the wind stream. The values of these corrections (of negligible consequence except in the case of high pitch settings and large advance ratios) were determined by calculations based on pressure observations.

The constant-speed efficiency curves were constructed in accordance with the method described in reference 9 and illustrated by figure 27 of that report.

The wake survey records were transposed from photographic to numerical form by means of the improved projection-measuring apparatus originally described in reference 10. This equipment enables direct tabulation of the slipstream pressures in terms of dynamic pressure, that is,  $P_{Tl}$ , rather than  $P_{tl}$ , is read directly from the projected record. These data, together with the results of free-stream yaw- and total-head calibrations, suffice for the evaluation of elementary torque and thrust coefficients by use of the formulas

$$\frac{dC_Q}{dx} = \frac{\pi x^2}{8} \left( \frac{V}{nD} \right)^2 \left( \frac{P_Y}{K} \right) \quad (3)$$

$$\frac{dC_T}{dx} = \frac{\pi x}{4} \left( \frac{V}{nD} \right)^2 (\Delta P) \quad (4)$$

Complete derivations of these equations are given in reference 10.

For the evaluation of  $dC_Q/dx$ , the experimentally determined values of  $P_Y$  were corrected by deduction of the small amounts of yaw-head-pressure unbalance recorded during final calibrations in the undisturbed stream. These corrections, in the cases of all but one of the groups of three heads, corresponded to an average misalignment of less than  $0.1^\circ$  and were accepted as practically unavoidable because their elimination would have required prohibitively laborious adjustment.

In connection with the evaluation of  $dC_T/dx$ , attention is called to the fact that  $\Delta P$  is less than  $\Delta P_T$ , the increase of total pressure caused by the propeller, and that its value must be deduced from that of the latter by auxiliary calculations.<sup>11</sup> In reference 10, the difference

$$E = \Delta P_T - \Delta P \quad (5)$$

was approximated by assuming that the induced axial inflow velocity which would correspond to uniform distribution of the measured total thrust prevailed at all points of the propeller disk. In the present calculations,  $E$  is evaluated by a process of successive approximations wherein the axial inflow velocity is deduced from local, rather than average, values. This method is outlined as follows.

In appendix I of reference 10 it is shown that

$$E = \frac{1}{4r^2} \left( \frac{P_Y}{K} \right)^2 \quad (6)$$

Since the values of  $P_Y$  and  $K$  are known, the determination of  $r$  (or  $1/4r^2$ ) enables the evaluation of  $E$ . (It should be noted that  $r = l + a$  and that  $a$  is the axial inflow factor.) The relationship between  $r$  and  $\Delta P$  furnishes the key to the problem; it is derived as follows.

By equating the alternative expressions for the thrust of the blade elements at a given radius

$$dT = \Delta p dA \quad (7)$$

$$dT = 2\rho V^2 a (l + a) dA \quad (8)$$

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<sup>11</sup>This refinement of previous practice was introduced in reference 10; the difference  $E$  (equation (5)) represents the dynamic pressure which corresponds to the tangential velocity of the slipstream just behind the propeller.

the thrust-producing pressure difference may be expressed as

$$\Delta p = 2\rho V^2 a(1 + a) \quad (9)$$

whence

$$a^2 + a - \Delta p / 2\rho V^2 = 0 \quad (10)$$

Introducing  $\Delta P = \Delta p / q = 2\Delta p / \rho V^2$ , equation (10) becomes

$$a^2 + a - \Delta P / 4 = 0 \quad (11)$$

Therefore

$$a = \frac{-1 \pm \sqrt{1 + \Delta P}}{2} \quad (12)$$

Selecting the positive sign so that  $r > 1$  when  $\Delta P > 0$ ,

$$r = 1 + a = \frac{1 + \sqrt{1 + \Delta P}}{2} \quad (13)$$

and

$$\frac{1}{4r^2} = \frac{1}{2 + 2\sqrt{1 + \Delta P} + \Delta P} \quad (14)$$

Thus the local value of  $1/4r^2$  is seen to be fully determined by that of  $\Delta P$ . The method of evaluating  $\Delta P$  by successive approximations can now be described in detail.

Taking an experimentally determined value of  $\Delta P_T$  as a rough approximation of  $\Delta P$ , the corresponding value of  $1/4r^2$  is obtained from a curve of  $1/4r^2$  against  $\Delta P$  prepared by use of equation (14). Introducing this value into equation (6), along with the experimentally determined value of  $P_y$  for the same station, a first approximation of  $E$  (i.e.,  $E_1$ ) is obtained. Subtraction of  $E_1$  from  $\Delta P_T$  yields the first real approximation of  $\Delta P$  (i.e.,  $\Delta P_1$ ). The process is now repeated by using  $\Delta P_1$  for determination of a second approximation of  $1/4r^2$ ;  $E_2$  is then obtained by use of equation (6) and subtracted from  $\Delta P_T$  to obtain  $\Delta P_2$ . In all but cases which involve very unusual values of  $\Delta P_T$  and  $P_y$ , subsequent repetitions of the process yield values of  $\Delta P$  indistinguishable from that of  $\Delta P_2$ . The method is, actually, not nearly so laborious as might be inferred from its

description because the lack of necessity for even a second approximation can frequently be determined by inspection.

A sample record and the corresponding computation sheet, which are reproduced as figures 12 and 13, respectively, illustrate the reduction of a complete set of wake survey data for a single condition of operation. The data read from the photographic record are the values of  $P_{T1}$ ,  $P_U$ , and  $P_D$ . The values of  $P_{T0}$  (which vary slightly with  $q$ ) and those of  $\Delta P_Y$  are obtained from the results of free-stream calibrations. The values of  $C_{T0}$  and  $C_Q$  (lower right corner of computation sheet) are obtained by integration of the thrust and torque grading curves. For comparison of the thrust coefficient determined by direct (dynamometer) measurement with that deduced from a wake survey,  $C_{T0}$  must be reduced by the amount  $\Delta C_T$  because surveys give no indication of spinner drag.<sup>12</sup>

## RESULTS

The characteristics of the seven models, as established by routine force tests, are shown in figures 14 to 20; each of these logarithmic charts depicts the characteristics of one model at six pitch settings. The corresponding numerical data will be found in tables 1 to 7.

Wake survey results are presented in the forms of thrust and torque grading curves. Each of the charts (figs. 21 to 32) contains the curves for models 1 to 6 at a single pitch setting; figures 33 and 34 present similar data for model 7, the transition model which differs from the others in blade profiles. In the interest of clarity, the definitive points are shown on only two sets of curves but these examples (figs. 25 and 26) may serve to emphasize the fact that the grading curves have been faithfully drawn through all plotted points and are, therefore, not to be interpreted as "faired results." Since the scale of these charts is necessarily small and because the data are believed to be of potential value for the analysis of various propeller problems, numerical results are also presented in tables 8 to 14.

## DISCUSSION

The recognized effect of solidity upon the constant-speed efficiency characteristics of propellers made the principal problem of designing blades for the present experiments that of insuring that the models of various plan forms would absorb substantially equal amounts of power under specified operating conditions. The selection of equality of the activity

<sup>12</sup>For discussion of correction and experimental data relative to drag of the spinner used in these tests, see reference 10, appendix III.

factors as a design criterion appeared to be reasonably well justified by empirical data and, as no more dependable one was known, the blade widths were adjusted upon that basis.

The measure of success achieved is illustrated by figure 35 in which the power coefficients attained by models 1 to 6, under conditions approximating those for maximum efficiency,<sup>13</sup> have been plotted against pitch angle. In order to avoid confusion, only the most widely separated curves are shown; the positions of the intermediate ones are indicated by the coordinates tabulated on the chart. As the values of  $C_p$  differ by less than 10 percent at all but the lowest pitch setting, it is believed that "effective solidity" - as measured by power absorption at maximum efficiency - has been equalized to an extent which precludes the ascribing of any major difference between the characteristics of the various models to this source. Thus blade-width distribution must be accepted as the primary, if not exclusive, cause of any consequential variation of properties revealed by the test results.

Examination and analysis of the test data may well be prefaced by comparison of the results of force tests and wake surveys. Whereas relatively satisfactory agreement between force and survey tests has been obtained in previous work involving propellers of small and moderate pitch (references 10 and 12), the only surveys which have been made of the wakes of high pitch models left much to be desired (see figs. 12 to 19, reference 10). In fact, under conditions of fully stalled operation at high pitch settings, the disagreement was so serious that even the qualitative significance of the corresponding thrust and torque grading curves appeared doubtful. In the present instance, improved apparatus and technique yield the gratifying results illustrated by figures 36 to 38; these charts pertain to the extremes of the plan-form series and include one variation of profile, that is, in model 7.

It will be seen that the power coefficients determined by wake surveys are in excellent agreement with force test results under all conditions and that such discrepancies of thrust as do occur are of relatively small magnitude and are confined to the lowest ranges of advance ratios. With reference to the thrust discrepancies, examination will reveal that, except in the case of model 7, the systematic deviation which occurs at low advance ratios with small and medium pitch angles disappears when the setting is increased to 48° and 60°. This obviously precludes ascription of the errors to blade stalling; their probable source is indicated by the following tabulation.

<sup>13</sup>The plotted values of  $C_p$  are those at which the experimental curves of  $C_p$  against  $V/nD$  intersect the straight line I-I which appears on each of the logarithmic charts (figs. 14 to 19). This is the "Line I" used in analysis of the results presented in references 9 and 10; it closely approximates the locus, in the  $V/nD$ ,  $C_p$  plane, of the points of maximum constant-speed efficiency ( $\partial\eta/\partial J = 0$ ) for propellers with three blades of activity factor 92.4. (See fig. D, reference 9.)

MAXIMUM INCREASE OF EFFECTIVE TOTAL PRESSURE  
AT MINIMUM ADVANCE RATIOS OF WAKE SURVEYS

$\beta_{0.75R}$ (deg)	$\Delta P_{2\max}$					
	12	19	27	37	48	60
Model						
1	3.68	5.24	5.15	4.00	2.39	1.36
5	3.51	5.24	4.57	3.41	1.89	.92
7	2.79	4.41	3.73	2.23	1.38	.69

Since the values of  $\Delta P_2$  are identical with those of the local Froude thrust coefficients ( $C_T' = T/qA$ ), it is clear that the discernable errors of thrust determination occur in conjunction with high static pressures in, and severe contraction of, the slipstream. It may prove difficult to eliminate wake survey errors under such conditions as these.

The cause of the thrust discrepancy in the case of model 7 at the  $60^\circ$  setting is, as yet, undetermined. Since the results for model 6 exhibit a similar peculiarity, plan form, rather than profile, would appear to be in some way responsible but the better agreement obtained with model 5, which also has narrow blade shanks, has thus far balked all attempts at analysis. With these limited and relatively minor exceptions, the agreement between force and survey test results is seen to be of such quality as to warrant confident acceptance of the wake data.

#### Results of Force Tests

Identification of the effects of varying the distribution of blade width is best begun by examining the fixed-pitch characteristics illustrated by figures 14 to 19.<sup>14</sup> One consistent difference between the properties of conventional and tapered blades is apparent at the outset. The curves of  $C_T$  and  $C_P$  against  $V/nD$  for the tapered blades (models 1, 2, 4, and 5) rise to higher values before flattening off and remain higher at reduced advance ratios than do the corresponding curves for the blades of more nearly uniform width (models 3 and 6). It will also be noted that the  $C_T$  curves for models 3 and 6 at the higher pitch settings are distinguished by more prominent peaks, and by deeper valleys adjacent thereto, than are the corresponding curves for the tapered blades.

<sup>14</sup> Note that model 7 is excluded from these comparisons because its blade profiles differ from those of models 1 to 6.

When the efficiency curves for equal pitch settings are compared, the uniformity of their peak values can hardly fail to be surprising in view of the substantial differences of power- and thrust-curve forms just noted. Such uniformity, however, does not characterize the shapes of the efficiency curves for the various models. The typical change of form which results from the introduction of pronounced taper is best illustrated by the curves for models 1 and 6 at the  $60^\circ$  setting; the elevation and straightening of the left side of the curve in the case of model 1 will be apparent upon inspection of figures 14 and 19.

Some further differences which are not apparent in the logarithmic charts are brought out by the Cartesian plots (fig. 39). There it will be seen that, in the unstalled range, the slopes of the curves of  $C_T$  and  $C_p$  against  $V/nD$  are almost imperceptibly affected by changes of plan form. On the other hand, the separation of the curves indicates a marked effect of blade-width distribution on the values of the advance ratio at which  $C_p$  and  $C_T$  would become zero. This effect, completely neglected in designing the blades for equal power absorption, is sufficient to account for practically all of the differences illustrated by figure 35.

The cause of the aforementioned separation is readily deduced from the thrust (or torque) grading curves. Reference to figures 21 to 32 shows that the angles of attack of the outer elements will be negative, and those of the inner ones positive, when the total thrust is zero.<sup>15</sup> Consider, now, a model with blades of uniform width operating at the advance ratio for zero total thrust. If blade area were taken from the neighborhood of the tips and an equivalent amount added near the roots, the equality of positive and negative thrust components would be destroyed, the total thrust would become positive, and an increase of advance ratio would be required to re-establish the initial condition of equilibrium. The tapered blades therefore attain zero thrust and torque at larger advance ratios than the ones of uniform width when both types have equal pitch settings at  $x = 0.75$ . Lest it be suspected that the separation of the curves for models 3 and 6 is inconsistent with this explanation, the reader is referred to figure 3 where it will be seen that model 6 is actually distinguished by slight "reverse taper," that is, the average width of the outer half of the blade is greater than that of the inner one.

In spite of all the differences which have been pointed out above, it is shown in figure 40 that the efficiency envelopes for models 1 to 6 are appreciably separated only at very large and very small advance ratios. (In order to avoid confusion in this chart, only those curves which define the upper and lower limits of the group are shown; numbered auxiliary lines identify the positions of the others.) The maximum ordinates

<sup>15</sup> An unavoidable consequence of the use of the envelope twist curve.

of all six curves are between 0.85 and 0.86. Since there is reason to believe that more nearly complete coincidence would have resulted if a more conventional pitch distribution had been incorporated in these models, it is hardly surprising that the results of early propeller tests — which were appraised almost exclusively upon the basis of maximum efficiencies — were interpreted as indicating that blade-width distribution had an inconsequential effect upon propulsive efficiency.

In striking contrast to the envelope curves, figures 41 to 45 reveal very substantial effects of plan-form variation upon constant-speed efficiency. In each of these charts, curves for model 6 are reproduced as a basis for comparisons. It will be seen at once that, as in the case which gave rise to this investigation, the effects of blade-width distribution are confined to advance ratios less than those for maximum efficiency and that their magnitude increases with that of the power coefficient. At  $C_p = 0.05$ , the smallest value for which efficiency curves have been constructed, model 3 is very slightly superior to model 6, whereas all the others are somewhat inferior. At larger power coefficients, the efficiencies of models 3 and 6 are practically indistinguishable. However, at  $C_p = 0.10$ , the beneficial effects of taper are clearly apparent and, as  $C_p$  continues to increase, the tapered blades — models 1, 2, 4, and 5 — exhibit increasing superiority over the conventional type throughout the ranges of reduced advance ratios. These divergences between corresponding constant-speed efficiency curves are the more notable because the peaks of corresponding curves are practically indistinguishable except in the case of the smallest power coefficient.

Of the four models which are superior to the conventional one, it will be noted that two (models 1 and 2) have blades which taper continuously from root to tip, while those of the other pair (models 4 and 5) are of the doubly tapered type, that is, their widths diminish from intermediate stations toward both root and tip. It will, therefore, be of interest to identify the better plan form of each type. By comparing the curves in figure 41 with those of figure 42, the efficiencies of model 1 will be found to exceed those of model 2; a similar comparison of figure 44 with figure 45 will establish the superiority of model 4 over model 5. It thus appears that the wider blade of each type is the more efficient.<sup>16</sup>

In order to summarize the most significant results of the force tests, typical constant-speed efficiency curves for models 1 and 4 have

<sup>16</sup>It is, of course, equally true to say that the one with the narrower tip, the more severe taper, or the broader root is the better; the number of models included in the present series was insufficient to enable positive identification of the most influential plan-form characteristic.

been superimposed upon corresponding curves for model 6 in figure 46. An auxiliary logarithmic scale has been placed alongside the curves for  $C_p = 0.5$  to enable convenient appraisal of the advantages of one type over another. Its use is illustrated by the dotted lines which show that, at  $C_p = 0.5$  and  $V/nD = 1.5$ , the replacement of model 6 by model 1 or 4 would have the result of augmenting the efficiency - and available thrust horsepower - by one-third or one-fourth, respectively. Although the advantages of the tapered plan forms diminish as the power coefficient becomes smaller, it is worth noting that they are still apparent at advance ratios less than 0.6 when  $C_p$  is only 0.10. Another feature worthy of note is the substantial parallelism of corresponding efficiency curves in the range of small advance ratios; as the coordinates of the chart are logarithmic, such parallelism implies the maintenance of a constant relative superiority throughout the take-off and low-speed climbing ranges.

When the foregoing results are viewed from the standpoint of practical applicability, it appears almost certain that the root width of model 1 will be considered prohibitively great for incorporation in a modern constant-speed propeller. On the other hand, this objection is not applicable to model 4, which closely approaches the performance of model 1. Furthermore it would appear reasonable to anticipate that further development of plan forms characterized by limited root widths will lead to substantial reproduction, if not improvement, of the characteristics of model 1. In this connection, attention is called to the unnecessarily great thickness of the inner sections of the heavily tapered blades. Corresponding elements of models 1 to 6 were made geometrically similar with the object of reducing the number of variables capable of influencing the test results; however, it should be duly noted that the practically allowable reductions of thickness in the cases of the tapered blades would certainly have beneficial effects upon their performance characteristics. Consequently, the merits of these unorthodox plan forms have been demonstrated under a handicap which would not have to be accepted in practice.

#### Results of Wake Surveys

While the consequences of varying the distribution of blade width are clearly shown by the force test results, the underlying causes of these effects are to be found only by analysis of the wake survey data, which were recorded with that principal objective in view. However, since the present surveys are considerably more comprehensive than any made heretofore, it would appear appropriate to preface the analysis by some comments upon the general character of the results of this major phase of the investigation.

A bird's-eye view of the principal effects of advance ratio and pitch setting upon the distributions of thrust and torque over blades

of conventional plan form may be obtained by inspection of figures 33 and 34, which contain the grading curves for model 7.<sup>17</sup> Perhaps the most noteworthy feature of these charts is the marked similarity between the forms of corresponding thrust and torque curves for the larger advance ratios, that is, those for completely unstalled operation. The advent of stalling is indicated by the disappearance of similarity between corresponding curves and is most marked in the outer portion of the blade. In this connection, it will be noted that there is a general tendency for the torque curves to expand radially, that is, to have substantial positive values at, and even beyond,  $x = 1.0$  as the advance ratio is reduced at the higher pitch settings. By comparison, it will be seen that the corresponding tendency on the part of the thrust curves is relatively slight.

At their inner ends, the slopes of both the thrust and torque curves increase as the advance ratio diminishes and it is worth noticing that the increase continues even after the tips stall. The usual outward displacement of the peaks of the grading curves with the increase of pitch setting and decrease of advance ratio will be observed; it is, of course, most apparent in the curves for small pitch settings which are characterized by considerable regions of negative thrust near the tips. The tall, narrow peaks at the tips of a few of the torque curves are seen to be associated with negative thrust on the outer portions of the blades; it is believed that they indicate only the existence of sharp discontinuities of tangential velocity at corresponding radii.

A particularly noteworthy feature of the grading curves for model 7 is the irregularity of their forms in the neighborhood of  $x = 0.8$ . As a transition from Clark Y to NACA 16-series profiles occurs there, the irregularity of the curves is ascribed to the change of section.

Turning now to the grading curves for models 1 to 6 (figs. 21 to 32), it may facilitate interpretation to keep in mind the fact that the curves for models 3 and 6 — which have blades of nearly uniform width — appear at the right-hand side of each chart, whereas those for models 1 and 4 — which have the narrowest tips — are shown on the left. The characteristic effects of plan-form variation upon the radial distributions of thrust and torque are illustrated very clearly by figures 27 and 28, which correspond to a pitch setting of  $37^\circ$ . By scanning the charts from left to right, it will be seen that the curves (particularly those for large advance ratios) are modified in qualitative accordance with the variations of blade width. The peaks of the curves and the centers of gravity of the areas which they enclose are shifted toward the tips as the width of the inner portion of the blade

<sup>17</sup>Grading curves for all six of the related models (models 1 to 6) at a single pitch setting appear in each of the preceding charts (figs. 21 to 32). This arrangement was chosen to facilitate visualization of the effects of plan-form variations under comparable conditions of operation.

is diminished and that of the tip increased. The shapes of the curves are even more radically altered at reduced advance ratios. While the phenomenon of stalling appears to have a relatively small effect upon the division of the total torque between inner and outer portions of the blades, a marked influence upon the corresponding distributions of thrust will be observed. The result is an augmentation of the dissimilarity between the grading curves for blades of conventional and tapered forms.

Inspection of the charts for other blade angles reveals that the phenomena associated with stalling tend to disappear as the pitch setting is reduced and to become accentuated as it is increased. It will be apparent, however, that, in the absence of stalling, the character of the modifications of thrust and torque distribution caused by changes of plan form is not seriously influenced by pitch setting. These two features are emphasized to call attention to their consistency with the results of the force tests, that is, the influences of blade-width distribution are confined to advance ratios less than those at which maximum efficiency is attained and they increase with power coefficient.

#### Analysis of Influence of Width Distribution

The conditions under which substantial differences between the constant-speed efficiency characteristics of the various blades occur can be identified by noting, in figures 41 to 45, the largest values of  $V/nD$  at which such differences are apparent — at given values of  $C_p$  — and then locating the corresponding points ( $V/nD$ ,  $C_p$ ) on the fixed-pitch performance charts (figs. 14 to 19). When this is done, it will be seen that constant-speed efficiency divergence accompanies or follows — but never precedes — the sharp changes of slope of the curves of  $C_p$  against  $V/nD$  which occur as the advance ratio is reduced.

As the flattening of the  $C_p$  curves is caused by progressive stalling of the blades, it is evident that variations of plan form might influence the performance characteristics by altering the radial extent of stalling under given operating conditions, by redistributing the loading in such fashion as to alter the consequences of the stalling of a given portion of the blade, or by a combination of the two effects. Appraisal of these possibilities is facilitated by consideration of the definition of the efficiency of a blade element

$$\eta_e = \frac{dC_T/dx}{dC_Q/dx} \left( \frac{V}{2\pi nD} \right) \quad (15)$$

This indicates that, at any given advance ratio, the relative efficiencies of the elements of a blade are directly proportional to the ratios of corresponding ordinates of the appropriate thrust and torque grading curves.

In the light of this index, the previously mentioned similarity between the thrust and torque grading curves for large advance ratios and the contrasting lack of resemblance between those for small ones become highly significant because the dissimilarities are of such character that marked reductions of efficiency over the outer portions of the blades are clearly indicated. An unmistakable example of such indication will be found in the grading curves for model 6 at the  $37^{\circ}$  pitch setting (figs. 27 and 28).

If it is now tentatively assumed that the outer elements of all the blades experience comparable reductions of efficiency as stalling progresses with reduction of the advance ratio and that their inboard elements operate at approximately equal, and much higher, efficiencies, it is clear the blades in which the inner, more efficient, elements absorb the larger fraction of the total torque input will develop the greater total thrust and higher over-all efficiency. In order to test the validity of this hypothesis, the radial distributions of torque and efficiency for blades of various plan forms must be examined under comparable conditions of operation.

A case in which large differences of constant-speed efficiency are known to develop at reduced advance ratios has been chosen for illustrative analysis. In figure 47, curves of  $dC_Q/dx$  and  $\eta_e$  against  $x$  for models 1, 4, and 6 at pitch settings of  $60^{\circ}$  have been plotted for three operating conditions. The curves of the upper pair of charts in this figure correspond, as closely as the recorded data permit, to the conditions under which maximum efficiency is attained by each model. Those of the middle charts correspond to advance ratios which approximate 0.8 of those for maximum efficiency, while the lower pair depict the distributions which prevail at approximately  $0.6J(\eta_{max})$ .

A general reduction of efficiency with decrease of advance ratio is evident in the differences between the upper and middle sets of efficiency curves but it will be noticed that the curve for each model has been depressed almost uniformly. However, the further loss of efficiency which occurs with reduction of the advance ratio to  $0.6J(\eta_{max})$  is seen to be highly nonuniform and, although the curves for the three models deviate more under this condition than at the larger advance ratios, all are characterized by serious reductions of efficiency over the outer portions of the blades and by relatively slight ones over the inner parts.

When these efficiency curves are interpreted in conjunction with the corresponding ones of torque distribution, the principal reason for the superiority of the tapered blades (models 1 and 4) at reduced advance ratios becomes unmistakable. With the tapered blades, a relatively large portion of the power input (total torque) is absorbed and converted into thrust at relatively high efficiency by the inboard elements, whereas, with blades of nearly uniform width, the fraction of the input absorbed by the efficient inner elements is much smaller and that inefficiently utilized by the stalled outboard elements is correspondingly augmented.

Charts similar to figure 47 have been prepared for the same models at smaller pitch settings but are not reproduced herein because they merely illustrate, in diminishing degree, the relationships brought out most clearly by the curves for the 60° blade angle. Whether due to the improved accuracy of survey under those conditions or to other causes, the curves of elementary efficiency for the lower pitches are less irregular and more nearly coincident than the 60° ones. Furthermore, it should not escape notice that the curves of figure 47 are not strictly comparable because models 1 and 4 are characterized by somewhat larger power coefficients at maximum efficiency with the 60° pitch setting than is model 6. Therefore, equalization of the power coefficients and advance ratios at which comparisons are made would bring the efficiency curves into closer coincidence than that illustrated by figure 47.

Thus the suggested hypothesis based on redistribution of loading has been qualitatively confirmed and it would appear to be useful as an approximate quantitative basis for prediction of the probable effects of other plan-form variations.

#### Independence of Blade Elements

The independence of blade elements predicted by Glauert (reference 13) has been substantially verified, insofar as the variation of pitch distribution is concerned, by the results of two previous investigations (references 10 and 14). However, in discussing the results presented in reference 10, the writer expressed doubt that similar confirmation would be obtained if plan form, rather than pitch distribution, were varied. Data obtained in the present experiments have therefore been examined with that question in mind and some comparative curves which appear significant are presented in figure 48.

The widths of the blades of models 1, 2, and 6, as may be seen in figure 3, are equal when  $x$  is slightly greater than 0.80. The values of the thrust coefficients for these elements of equal chord have been read from the corresponding thrust grading curves and are plotted against advance ratio in the upper chart of figure 48. It will be seen that the curves for these identical elements of the three models of different plan forms exhibit consistent differences. The analogous curves in the lower chart of figure 48 indicate the existence of even larger discrepancies in the case of comparable elements of models 3 and 4. It will be noted that the separations of the curves are greatest at the smallest pitch settings; for that reason, and because of their greater irregularity, results for the larger pitch settings are not included.

The forces on other pairs of identical elements located at smaller distances from the axis than those of figure 48 have been compared and, as might be expected, the discrepancies are generally somewhat less than those for the outboard elements.

No entirely satisfying explanation of the discrepancies revealed by figure 48 has yet been evolved. It is evident that, under identical

conditions of operation, the outer elements of tapered blades develop smaller thrusts than do the corresponding ones of blades in which the width is nearly uniform. This, it will be noted, is the reverse of the relationship between the total thrust coefficients for the same blades. (See fig. 39.) The possibility that the discrepancies originate in differences of pitch setting is thus excluded. But since direct analogy with monoplane wings would lead to the expectation of larger, rather than smaller, forces on an outboard element of the tapered blade, the explanation of these results must await further analysis.

The net result of this critical examination is, however, unmistakable. The principle of independence is seen to be inapplicable at least to the outer elements of blades which have different plan forms.

#### Pitch Distribution and Profiles

The envelope pitch distribution incorporated in the models used for the present experiments was selected on the basis of the extrapolations summarized in figure 39 of reference 9. The expected characteristics were realized under some conditions of operation but not under others.

Models designated 0.4E, 0.6E, and 0.8E have been tested previously (reference 9); the designations indicate that the twist curves of these blades have ordinates 0.4, 0.6, and 0.8 times those of the envelope twist curve defined by equation (2). Model 7, the transition model of the present series, is the 1.0E member of that family. The effects of this further increase of blade twist are illustrated by figures 49 and 50.

Figure 49 shows that the maximum ordinate of the efficiency envelope for model 7 (1.0E) is, in accordance with expectations, somewhat greater than that of model 0.8E, but the extent of the depression of the left-hand portion of the curve is surprisingly great. These characteristics are reflected in the constant-speed efficiency curves of figure 50 where another, and unexpected, shortcoming of model 7 is revealed. This is the serious loss of efficiency which occurs when the advance ratio is reduced at large power coefficients. Reference to figure 39, reference 9, will show that the efficiency of a 1.0E model at  $C_p = 0.5$  and  $V/ND = 1.71$  was expected to be approximately 54 percent; the value actually realized under these conditions is only about 44 percent. It thus appears that blades of both uniform design pitch and envelope types suffer severe losses of efficiency under the conditions associated with climb at high power when the pitch distribution is such as to make the geometric angle of attack very nearly uniform over the entire length of the blade. To be sure, the constant-speed efficiency curve for model 7 degenerates rather suddenly as  $C_p$  increases from 0.4 to 0.5 but the relationship between the two families of curves in figure 50 leaves no question that, except for a slight advantage of peak efficiency, model 7, with its 1.0E pitch distribution, is generally inferior to model 0.8E.

Figure 51 illustrates the results of replacing the Clark Y and (small design lift coefficient) 16-series profiles of model 7<sup>18</sup> by the 16-series profiles of 0.7 design lift coefficient which characterize models 1 to 6. It is apparent without detailed examination that this change neutralizes the greater part of the adverse effect produced by adoption of the envelope pitch distribution, but it is also evident that use of the more highly cambered profiles has reduced the maximum efficiencies attained at all power coefficients. As the loss of peak efficiency is most serious at small power coefficients and as the divergence of corresponding curves increases with the advance ratio in all cases, it would appear almost certain that excessive profile drag at small lift coefficients is the source of this undesirable effect.

Consideration of the foregoing results leads to the conclusion that the twist incorporated in these models was too great to yield optimum characteristics and that one of approximately 0.8E form is most suitable for the blades of constant-speed propellers which are to be utilized over wide ranges of power coefficient and advance ratio. Further, it would appear that the use of such highly cambered profiles should be avoided unless it is absolutely essential to the suppression of shock stalling in heavily loaded propellers.

It appears possible that the preceding considerations may have created the impression that the inferior pitch distribution and high-camber profiles of the models used for these experiments have enhanced the opportunities for demonstration of the potential benefits of plan-form modification. The reader who entertains such misgivings may quickly dispel them by comparing the constant-speed efficiency curves of model 6 with those of model 0.8E (figs. 50 and 51); he will find them inconsequentially different except in peak height. Thus, the characteristics of the conventional type used as a basis of comparison throughout this discussion are not appreciably inferior, as regards efficiency at reduced advance ratios, to those of one characterized by more suitable profiles and a better pitch distribution. In view of this fact, most of the superiority, at reduced advance ratios, of the constant-speed efficiency curves for models 1 and 4 over those of model 0.8E (figs. 41, 44, and 50) can only be ascribed to the influence of blade-width distribution.

#### CONCLUSIONS

The most important result of combined force and wake survey tests on three-blade model propellers is the demonstration that blade-width distribution has a marked influence on the constant-speed efficiency characteristics of propellers.

<sup>18</sup>Also incorporated in all members of the E-series.

The envelope efficiency curves for the types of blades tested differ appreciably only at advance ratios less than 1.0 and greater than 3.0; in those ranges, the envelope efficiencies of the relatively straight blades are slightly superior to those of the tapered ones. However, the constant-speed efficiency curves diverge substantially as the advance ratios are reduced below the values at which maximum efficiencies occur. At these reduced advance ratios, and at all values of power coefficient equal to or greater than 0.1, blades tapered from broad roots to narrow tips attained greater efficiencies than did those of relatively uniform width. At power coefficients appreciably less than 0.1, untapered blades were found to be somewhat more efficient than tapered ones at all advance ratios. Similar, and only slightly smaller, differences of constant-speed efficiency occurred when the continuously tapered blades were replaced by a more practical type characterized by a considerable reduction of width close to the root.

The more efficient operation of the tapered blades at reduced advance ratios is ascribed to a redistribution of loading which serves to minimize the absorption of power by the outer elements — which become very inefficient as they stall — and to correspondingly augment the fraction of input which is efficiently converted into thrust by the unstalled, inboard elements.

An incidental result of fundamental importance is the failure of the present wake survey data to confirm the theory of blade-element independence. It is noted that apparent verification has been accomplished by previous experiments in which only pitch distribution, rather than plan form, was varied.

Correlation of the present results with those of preceding studies indicates that highly cambered profiles are not generally suitable for propeller blades and that the so-called "envelope" pitch distribution is inferior to one derived therefrom by proportionate reduction of the angles of twist.

Stanford University  
Stanford University, Calif., May 25, 1946

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TABLE 1.— FORCE TEST DATA; MODEL 1

$\beta_{0.75R} = 60^\circ$							
Test E-1				Test E-2			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
3.724	0.7766	0.1511	0.725	3.804	0.7396	0.1390	0.715
3.580	.8318	.1756	.756	3.664	.7950	.1608	.741
3.473	.8651	.1903	.764	3.508	.8446	.1827	.759
3.301	.8973	.2127	.782	3.357	.8902	.2061	.777
3.162	.8863	.2194	.783	3.219	.8907	.2163	.782
3.004	.8553	.2224	.781	3.078	.8679	.2215	.786
2.866	.8332	.2261	.778	2.936	.8404	.2245	.784
2.715	.8140	.2295	.765	2.794	.8206	.2307	.785
2.582	.7978	.2319	.751	2.648	.8043	.2329	.767
2.419	.7777	.2251	.700	2.491	.7860	.2288	.725
2.281	.7473	.2134	.651	2.349	.7626	.2210	.681
2.136	.7157	.2022	.603	2.221	.7335	.2095	.634
1.993	.6930	.1917	.551	2.078	.7053	.1975	.582
1.856	.6753	.1848	.508	1.938	.6818	.1897	.539
1.706	.6702	.1837	.468	1.796	.6727	.1852	.494
1.550	.6746	.1836	.422	1.648	.6707	.1847	.454
1.425	.6743	.1838	.388	1.503	.6727	.1862	.416
1.284	.6773	.1852	.351	1.364	.6720	.1859	.377
1.148	.6736	.1855	.316	1.215	.6717	.1866	.338
1.001	.6763	.1870	.277	1.074	.6731	.1881	.300
.871	.6708	.1862	.242	.927	.6721	.1886	.260
.733	.6700	.1865	.204	.792	.6666	.1896	.225
$\beta_{0.75R} = 48^\circ$							
Test E-3				Test E-4			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
2.708	0.1811	0.0442	0.660	2.585	0.2366	0.0726	0.794
2.643	.2084	.0573	.727	2.485	.2756	.0900	.811
2.529	.2577	.0817	.801	2.373	.3252	.1141	.833
2.425	.3021	.1035	.831	2.276	.3718	.1388	.850
2.325	.3482	.1252	.836	2.171	.4069	.1589	.848
2.227	.3913	.1464	.833	2.070	.4223	.1739	.852
2.121	.4196	.1682	.850	1.963	.4230	.1807	.836
2.021	.4254	.1773	.842	1.857	.4205	.1874	.827
1.922	.4243	.1852	.839	1.754	.4221	.1943	.807
1.819	.4249	.1910	.818	1.650	.4253	.1992	.773
1.712	.4254	.1979	.796	1.554	.4308	.2007	.724
1.621	.4326	.2021	.757	1.452	.4283	.1966	.667
1.512	.4328	.1996	.697	1.354	.4268	.1945	.617
1.410	.4292	.1966	.646	1.256	.4287	.1946	.570
1.309	.4287	.1945	.593	1.154	.4355	.1984	.526
1.222	.4334	.1970	.555	1.044	.4462	.2032	.475
1.116	.4423	.2014	.508	.955	.4539	.2066	.435
1.011	.4514	.2053	.460	.855	.4638	.2116	.390
.915	.4588	.2091	.417	.759	.4705	.2140	.345
.807	.4667	.2126	.368	.658	.4761	.2172	.300
.709	.4740	.2158	.323	.575	.4802	.2191	.262
.619	.4808	.2187	.282				
.523	.4845	.2210	.239				

TABLE 1.- FORCE TEST DATA; MODEL 1 - Continued

$\beta_{0.75R} = 37^\circ$							
Test E-5				Test E-6			
V/nD	C <sub>P</sub>	C <sub>T</sub>	$\eta$	V/nD	C <sub>P</sub>	C <sub>T</sub>	$\eta$
1.786	0.1140	0.0503	0.788	1.806	0.1025	0.0426	0.751
1.702	.1428	.0689	.821	1.741	.1273	.0587	.802
1.634	.1633	.0844	.844	1.670	.1513	.0753	.831
1.570	.1930	.1052	.856	1.600	.1802	.0954	.847
1.494	.2198	.1254	.852	1.526	.2093	.1176	.857
1.415	.2381	.1418	.843	1.452	.2332	.1369	.852
1.348	.2443	.1516	.836	1.386	.2430	.1489	.849
1.277	.2449	.1591	.830	1.312	.2444	.1560	.837
1.204	.2468	.1665	.812	1.231	.2447	.1626	.818
1.124	.2500	.1753	.788	1.160	.2476	.1707	.800
1.055	.2563	.1839	.757	1.088	.2507	.1783	.774
.967	.2640	.1884	.690	1.016	.2587	.1861	.731
.910	.2702	.1888	.636	.941	.2671	.1894	.667
.836	.2779	.1904	.573	.865	.2728	.1881	.596
.762	.2837	.1934	.519	.796	.2808	.1915	.543
.694	.2914	.1981	.472	.725	.2878	.1959	.493
.617	.3015	.2056	.421	.655	.2960	.2017	.446
.555	.3091	.2103	.378	.584	.3047	.2078	.398
.477	.3158	.2149	.325	.513	.3122	.2125	.349
.407	.3236	.2204	.277	.437	.3204	.2182	.298
				.387	.3245	.2210	.264
$\beta_{0.75R} = 27^\circ$							
Test E-7				Test E-8			
V/nD	C <sub>P</sub>	C <sub>T</sub>	$\eta$	V/nD	C <sub>P</sub>	C <sub>T</sub>	$\eta$
1.293	0.0434	0.0207	0.618	1.247	0.0572	0.0339	0.739
1.232	.0648	.0397	.754	1.187	.0745	.0512	.816
1.169	.0807	.0561	.813	1.126	.0937	.0694	.833
1.108	.0990	.0749	.838	1.064	.1109	.0874	.839
1.037	.1187	.0952	.832	1.008	.1259	.1043	.835
.980	.1332	.1122	.825	.947	.1394	.1214	.825
.917	.1454	.1291	.814	.885	.1484	.1354	.807
.857	.1504	.1397	.796	.819	.1499	.1440	.787
.794	.1510	.1466	.771	.759	.1490	.1502	.765
.732	.1498	.1526	.746	.699	.1497	.1568	.732
.675	.1506	.1593	.714	.639	.1512	.1648	.696
.613	.1516	.1672	.676	.582	.1525	.1709	.652
.552	.1558	.1759	.623	.519	.1577	.1794	.590
.490	.1617	.1822	.552	.459	.1655	.1855	.514
.424	.1714	.1861	.460	.399	.1740	.1866	.428
.372	.1784	.1880	.392	.334	.1814	.1892	.348
.306	.1866	.1919	.314				

TABLE 1.- FORCE TEST DATA; MODEL 1 - Concluded

$\beta_{0.75R} = 19^\circ$							
Test E-9				Test E-10			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
0.891	0.0385	0.0278	0.643	0.909	0.0334	0.0221	0.602
.838	.0507	.0452	.747	.856	.0459	.0388	.724
.786	.0612	.0604	.776	.810	.0557	.0532	.773
.737	.0711	.0760	.788	.756	.0663	.0692	.789
.687	.0796	.0889	.767	.702	.0762	.0845	.779
.633	.0858	.1023	.755	.657	.0826	.0968	.770
.584	.0913	.1149	.735	.604	.0889	.1098	.746
.533	.0945	.1251	.706	.561	.0926	.1201	.727
.484	.0957	.1334	.675	.505	.0946	.1295	.691
.430	.0960	.1413	.633	.454	.0956	.1371	.651
.382	.0959	.1475	.588	.406	.0957	.1438	.609
.332	.0948	.1523	.533	.357	.0952	.1490	.559
.276	.0949	.1593	.463	.311	.0943	.1543	.510
.230	.0944	.1635	.398	.236	.0938	.1624	.409
				.206	.0939	.1653	.362
$\beta_{0.75R} = 12^\circ$							
Test E-11				Test E-12			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
.608	0.0286	0.0223	0.474	0.585	0.0322	0.0298	0.541
.568	.0340	.0339	.566	.545	.0373	.0415	.606
.526	.0395	.0462	.615	.507	.0420	.0523	.631
.488	.0437	.0568	.634	.465	.0462	.0638	.642
.452	.0475	.0670	.638	.424	.0497	.0741	.632
.407	.0509	.0780	.624	.386	.0525	.0832	.612
.367	.0536	.0873	.598	.345	.0547	.0921	.581
.330	.0557	.0958	.568	.308	.0566	.1003	.546
.284	.0571	.1047	.521	.264	.0577	.1083	.496
.248	.0579	.1111	.476	.218	.0583	.1159	.433
.204	.0588	.1184	.411				

TABLE 2.- FORCE TEST DATA; MODEL 2

$\beta_{0.75R} = 60^\circ$							
Test D-1				Test D-2			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
3.689	0.7567	0.1527	0.744	3.611	0.779	0.1622	0.752
3.540	.8129	.1780	.775	3.480	.847	.1828	.751
3.405	.8595	.1994	.790	3.323	.859	.2041	.790
3.265	.8512	.2067	.793	3.188	.840	.2086	.792
3.120	.8261	.2106	.795	3.044	.810	.2106	.791
2.984	.8020	.2145	.798	2.890	.787	.2147	.788
2.837	.7831	.2184	.791	2.780	.777	.2189	.783
2.696	.7685	.2219	.778	2.628	.766	.2236	.767
2.551	.7636	.2252	.752	2.485	.758	.2240	.734
2.402	.7470	.2183	.702	2.334	.728	.2082	.667
2.261	.7095	.1993	.635	2.196	.691	.1917	.609
2.118	.6710	.1836	.580	2.050	.658	.1786	.556
1.976	.6475	.1722	.526	1.910	.641	.1700	.506
1.872	.6311	.1677	.497	1.773	.628	.1669	.471
1.708	.6249	.1650	.451	1.620	.627	.1654	.427
1.563	.6300	.1665	.413	1.486	.639	.1682	.391
1.422	.6356	.1677	.375	1.344	.642	.1698	.355
1.278	.6400	.1693	.338	1.200	.648	.1708	.316
1.139	.6407	.1700	.302	1.063	.647	.1722	.283
.998	.6411	.1716	.267	.896	.646	.1719	.238
.868	.6419	.1713	.232	.771	.645	.1721	.206
.710	.6385	.1714	.191				
$\beta_{0.75R} = 48^\circ$							
Test D-3				Test D-4			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
2.586	0.2236	0.0653	0.755	2.658	0.198	0.0535	0.718
2.470	.2745	.0897	.807	2.604	.217	.0631	.757
2.367	.3196	.1124	.832	2.533	.247	.0769	.789
2.264	.3668	.1354	.836	2.434	.297	.0994	.815
2.170	.4016	.1573	.850	2.328	.344	.1231	.833
2.066	.4117	.1690	.848	2.232	.388	.1474	.848
1.969	.4105	.1751	.840	2.130	.411	.1642	.851
1.864	.4095	.1818	.828	2.019	.410	.1715	.845
1.760	.4100	.1892	.812	1.918	.410	.1784	.835
1.657	.4128	.1952	.784	1.813	.408	.1847	.821
1.559	.4225	.1973	.728	1.714	.412	.1924	.800
1.458	.4183	.1890	.659	1.613	.419	.1974	.760
1.354	.4135	.1838	.602	1.511	.422	.1931	.691
1.255	.4140	.1836	.557	1.407	.416	.1858	.628
1.159	.4186	.1856	.514	1.308	.416	.1844	.580
1.058	.4256	.1885	.468	1.216	.419	.1860	.540
.956	.4330	.1909	.421	1.114	.425	.1879	.493
.857	.4427	.1948	.377	1.021	.432	.1911	.452
.755	.4522	.1988	.332	.915	.441	.1947	.404
.655	.4603	.2022	.288	.806	.450	.1977	.354
.541	.4676	.2052	.237	.710	.461	.2029	.312
				.608	.465	.2040	.267
				.521	.472	.2065	.228

TABLE 2.— FORCE TEST DATA; MODEL 2 — Continued

$\beta_{0.75R} = 37^\circ$							
Test D-5				Test D-6			
V/nd	$C_P$	$C_T$	$\eta$	V/nd	$C_P$	$C_T$	$\eta$
1.805	0.1001	0.0407	0.734	1.745	0.1208	0.0558	0.806
1.740	.1190	.0536	.784	1.668	.1507	.0756	.837
1.669	.1476	.0735	.831	1.608	.1707	.0903	.850
1.595	.1763	.0936	.847	1.538	.1961	.1086	.851
1.522	.2041	.1146	.855	1.463	.2240	.1298	.848
1.448	.2269	.1341	.856	1.389	.2362	.1443	.849
1.379	.2364	.1455	.849	1.320	.2357	.1497	.838
1.306	.2370	.1523	.839	1.243	.2357	.1564	.825
1.230	.2378	.1583	.819	1.172	.2382	.1639	.806
1.158	.2398	.1662	.803	1.101	.2401	.1700	.780
1.083	.2424	.1730	.773	1.030	.2459	.1776	.744
1.011	.2496	.1799	.729	.958	.2556	.1826	.684
.938	.2587	.1834	.665	.886	.2627	.1804	.608
.866	.2662	.1810	.589	.821	.2673	.1801	.553
.796	.2712	.1821	.534	.743	.2743	.1827	.495
.725	.2776	.1849	.483	.682	.2803	.1865	.454
.651	.2844	.1892	.433	.606	.2873	.1903	.401
.579	.2912	.1928	.383	.548	.2953	.1948	.361
.514	.2974	.1960	.339	.464	.3009	.1984	.306
.441	.3026	.2000	.291	.400	.3051	.2011	.264
.387	.3085	.2023	.254				

$\beta_{0.75R} = 27^\circ$							
Test D-7				Test D-8			
V/nd	$C_P$	$C_T$	$\eta$	V/nd	$C_P$	$C_T$	$\eta$
1.242	0.0546	0.0321	0.731	1.265	0.0482	0.0241	0.633
1.179	.0749	.0512	.807	1.218	.0618	.0384	.757
1.120	.0930	.0688	.828	1.156	.0808	.0569	.814
1.058	.1101	.0873	.839	1.093	.1006	.0767	.833
.996	.1248	.1042	.832	1.031	.1158	.0936	.834
.936	.1374	.1209	.824	.969	.1307	.1118	.829
.877	.1428	.1326	.814	.911	.1403	.1256	.816
.814	.1435	.1393	.790	.850	.1439	.1357	.802
.755	.1434	.1454	.766	.789	.1439	.1420	.779
.695	.1434	.1516	.735	.726	.1437	.1480	.748
.634	.1447	.1583	.694	.664	.1438	.1542	.712
.572	.1471	.1651	.642	.615	.1456	.1610	.680
.514	.1523	.1695	.572	.545	.1496	.1680	.612
.459	.1583	.1739	.504	.484	.1557	.1728	.537
.393	.1656	.1762	.418	.435	.1611	.1735	.468
.334	.1728	.1787	.345	.367	.1686	.1767	.385
				.324	.1739	.1790	.334

TABLE 2.— FORCE TEST DATA; MODEL 2 — Concluded

$\beta_{0.75R} = 19^\circ$							
Test D-9				Test D-10			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
0.913	0.0299	0.0169	0.516	0.881	0.0368	0.0267	0.639
.857	.0421	.0340	.691	.833	.0476	.0422	.739
.807	.0540	.0506	.757	.781	.0589	.0582	.771
.757	.0636	.0657	.783	.732	.0684	.0735	.786
.707	.0726	.0804	.783	.683	.0759	.0865	.779
.656	.0801	.0939	.770	.629	.0826	.1000	.761
.605	.0853	.1058	.750	.581	.0867	.1106	.742
.556	.0884	.1154	.726	.530	.0886	.1192	.713
.505	.0896	.1236	.697	.481	.0893	.1267	.683
.455	.0899	.1304	.660	.429	.0895	.1332	.639
.406	.0904	.1373	.617	.375	.0898	.1408	.588
.360	.0902	.1428	.570	.331	.0896	.1463	.541
.305	.0895	.1484	.506	.277	.0888	.1505	.470
.266	.0893	.1523	.454	.228	.0883	.1552	.401
.203	.0896	.1584	.359				
$\beta_{0.75R} = 12^\circ$							
Test D-11				Test D-12			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
0.585	0.0292	0.0240	0.486	0.603	0.0264	0.0188	0.429
.545	.0342	.0358	.570	.567	.0313	.0295	.534
.508	.0385	.0473	.624	.525	.0366	.0421	.604
.466	.0431	.0591	.639	.488	.0408	.0532	.636
.423	.0467	.0695	.629	.444	.0446	.0643	.641
.384	.0489	.0780	.613	.408	.0475	.0735	.631
.345	.0509	.0869	.588	.363	.0504	.0839	.604
.309	.0520	.0933	.555	.325	.0515	.0912	.576
.260	.0533	.1023	.498	.284	.0529	.0987	.531
.215	.0537	.1095	.438	.250	.0533	.1044	.490

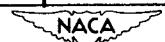


TABLE 3.— FORCE TEST DATA; MODEL 3

$\beta_{0.75R} = 60^\circ$							
Test G-1				Test G-2			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
3.686	0.7099	0.1459	0.758	3.652	0.7243	0.1508	0.760
3.551	.7576	.1679	.787	3.474	.7805	.1778	.791
3.403	.7866	.1843	.797	3.332	.7838	.1881	.800
3.276	.7731	.1897	.804	3.217	.7667	.1909	.801
3.120	.7469	.1913	.799	3.079	.7404	.1934	.804
2.969	.7284	.1952	.796	2.934	.7283	.1965	.792
2.843	.7186	.1998	.790	2.791	.7146	.2016	.787
2.695	.7113	.2042	.774	2.642	.7056	.2031	.760
2.548	.7020	.2027	.736	2.512	.6996	.2025	.727
2.404	.6805	.1919	.678	2.324	.6679	.1838	.640
2.262	.6461	.1733	.607	2.196	.6273	.1654	.579
2.135	.6174	.1599	.553	2.058	.5972	.1528	.527
1.980	.5890	.1480	.498	1.928	.5805	.1448	.481
1.840	.5770	.1416	.452	1.781	.5673	.1392	.437
1.688	.5690	.1387	.411	1.640	.5719	.1389	.398
1.553	.5789	.1403	.376	1.492	.5814	.1418	.364
1.410	.5827	.1403	.339	1.346	.5852	.1412	.325
1.264	.5867	.1412	.304	1.208	.5921	.1425	.291
1.138	.5924	.1431	.275	1.067	.5934	.1448	.260
.995	.6004	.1463	.242	.911	.5993	.1492	.227
.862	.5977	.1484	.214	.784	.5948	.1497	.197
.719	.5980	.1498	.180				

$\beta_{0.75R} = 48^\circ$							
Test G-3				Test G-4			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
2.537	0.2239	0.0687	0.778	2.627	0.1768	0.0478	0.701
2.441	.2626	.0866	.805	2.580	.2030	.0585	.743
2.356	.2946	.1025	.820	2.487	.2465	.0792	.799
2.251	.3429	.1295	.850	2.385	.2898	.1004	.826
2.157	.3693	.1468	.857	2.279	.3356	.1239	.841
2.058	.3757	.1546	.847	2.182	.3692	.1434	.848
1.946	.3782	.1618	.833	2.071	.3771	.1544	.848
1.843	.3797	.1701	.826	1.985	.3796	.1609	.841
1.748	.3816	.1751	.802	1.874	.3832	.1679	.821
1.649	.3856	.1777	.760	1.788	.3828	.1738	.812
1.548	.3866	.1743	.698	1.688	.3866	.1781	.778
1.442	.3846	.1678	.629	1.592	.3887	.1777	.728
1.352	.3848	.1647	.579	1.486	.3870	.1698	.652
1.255	.3860	.1647	.535	1.383	.3842	.1650	.594
1.144	.3902	.1649	.483	1.287	.3862	.1637	.546
1.037	.3966	.1661	.434	1.187	.3873	.1633	.500
.946	.4043	.1689	.395	1.087	.3905	.1638	.456
.850	.4148	.1727	.354	.989	.4007	.1667	.411
.747	.4230	.1752	.309	.893	.4116	.1711	.371
.647	.4297	.1784	.269	.793	.4206	.1763	.332
.567	.4373	.1814	.235	.697	.4287	.1778	.289
				.591	.4384	.1816	.245
				.498	.4453	.1848	.207

TABLE 3.- FORCE TEST DATA; MODEL 3 - Continued

$\beta_{0.75R} = 37^\circ$							
Test G-5				Test G-6			
V/nD	C <sub>P</sub>	C <sub>T</sub>	$\eta$	V/nD	C <sub>P</sub>	C <sub>T</sub>	$\eta$
1.803	0.0821	0.0324	0.711	1.755	0.0981	0.0424	0.759
1.726	.1120	.0511	.787	1.682	.1263	.0614	.818
1.653	.1425	.0702	.814	1.613	.1532	.0795	.837
1.588	.1642	.0872	.843	1.541	.1788	.0980	.845
1.512	.1929	.1091	.855	1.471	.2026	.1179	.856
1.443	.2109	.1252	.857	1.397	.2110	.1291	.855
1.367	.2139	.1331	.851	1.325	.2131	.1353	.841
1.293	.2171	.1402	.835	1.254	.2160	.1419	.824
1.224	.2192	.1467	.819	1.180	.2191	.1499	.807
1.153	.2234	.1538	.794	1.108	.2252	.1572	.773
1.076	.2279	.1604	.757	1.036	.2320	.1625	.726
1.002	.2359	.1642	.697	.966	.2361	.1622	.664
.931	.2403	.1618	.627	.895	.2412	.1606	.596
.856	.2458	.1614	.562	.823	.2477	.1617	.537
.788	.2542	.1642	.509	.749	.2554	.1649	.484
.715	.2624	.1678	.457	.680	.2625	.1685	.436
.643	.2671	.1706	.411	.608	.2669	.1703	.388
.576	.2726	.1732	.366	.537	.2730	.1733	.341
.510	.2768	.1751	.323	.465	.2785	.1761	.291
.431	.2826	.1780	.271	.393	.2843	.1792	.248
.380	.2880	.1803	.238				
$\beta_{0.75R} = 27^\circ$							
Test G-7				Test G-8			
V/nD	C <sub>P</sub>	C <sub>T</sub>	$\eta$	V/nD	C <sub>P</sub>	C <sub>T</sub>	$\eta$
1.243	0.0445	0.0240	0.670	1.267	0.0376	0.0179	0.603
1.186	.0646	.0418	.767	1.213	.0560	.0349	.756
1.119	.0817	.0597	.818	1.149	.0748	.0521	.800
1.062	.0980	.0771	.836	1.085	.0926	.0708	.830
1.001	.1140	.0954	.838	1.027	.1072	.0871	.834
.938	.1248	.1103	.829	.969	.1212	.1043	.834
.881	.1288	.1201	.821	.907	.1287	.1166	.822
.818	.1287	.1250	.794	.844	.1288	.1226	.803
.757	.1296	.1314	.768	.786	.1294	.1277	.776
.697	.1304	.1376	.735	.726	.1307	.1345	.747
.637	.1330	.1444	.692	.664	.1321	.1414	.711
.574	.1393	.1508	.621	.601	.1361	.1474	.651
.516	.1446	.1524	.544	.542	.1412	.1506	.578
.459	.1496	.1535	.471	.485	.1473	.1528	.503
.397	.1553	.1565	.400	.424	.1518	.1541	.430
.334	.1606	.1599	.333	.363	.1574	.1574	.363
				.316	.1616	.1598	.312

TABLE 3.- FORCE TEST DATA; MODEL 3 - Concluded

$\beta_{0.75R} = 19^\circ$							
Test G-9				Test G-10			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
0.904	0.0258	0.0166	0.582	0.875	0.0330	0.0254	0.673
.855	.0388	.0323	.712	.822	.0447	.0411	.757
.804	.0491	.0467	.764	.776	.0538	.0552	.795
.752	.0586	.0610	.783	.728	.0622	.0675	.789
.702	.0670	.0758	.795	.679	.0704	.0819	.790
.653	.0740	.0893	.788	.628	.0768	.0947	.774
.603	.0793	.1002	.761	.577	.0801	.1036	.747
.547	.0810	.1091	.736	.525	.0803	.1103	.721
.500	.0810	.1142	.705	.478	.0808	.1162	.688
.453	.0804	.1187	.669	.428	.0800	.1206	.645
.402	.0800	.1233	.620	.379	.0795	.1256	.599
.350	.0799	.1290	.565	.328	.0796	.1311	.540
.303	.0808	.1337	.501	.275	.0814	.1362	.460
.256	.0826	.1377	.426	.227	.0836	.1395	.378
.202	.0854	.1412	.335				
$\beta_{0.75R} = 12^\circ$							
Test G-11				Test G-12			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
0.582	0.0244	0.0213	0.507	0.597	0.0229	0.0187	0.487
.541	.0297	.0335	.611	.560	.0271	.0288	.595
.500	.0342	.0447	.654	.520	.0320	.0407	.662
.465	.0379	.0552	.676	.482	.0362	.0501	.668
.424	.0420	.0655	.660	.437	.0407	.0621	.668
.384	.0444	.0739	.639	.401	.0435	.0711	.656
.346	.0459	.0815	.615	.361	.0451	.0786	.630
.310	.0466	.0871	.578	.319	.0459	.0860	.598
.265	.0469	.0945	.533	.282	.0468	.0917	.552
.217	.0475	.1014	.464	.248	.0469	.0971	.513
				.182	.0471	.1065	.411



TABLE 4.- FORCE TEST DATA; MODEL 4

$$\beta_{0.75R} = 60^\circ$$

Test C-1				Test C-2			
V/nD	C <sub>P</sub>	C <sub>T</sub>	η	V/nD	C <sub>P</sub>	C <sub>T</sub>	η
3.713	0.7655	0.1572	0.762	3.658	0.7842	0.1641	0.770
3.552	.8296	.1805	.773	3.477	.8408	.1904	.787
3.402	.8659	.2022	.794	3.345	.8737	.2109	.807
3.268	.8718	.2139	.802	3.200	.8584	.2138	.797
3.130	.8439	.2152	.798	3.052	.8229	.2159	.801
2.978	.8113	.2165	.795	2.905	.7994	.2193	.797
2.835	.7902	.2198	.789	2.776	.7822	.2213	.785
2.693	.7735	.2228	.776	2.630	.7627	.2240	.772
2.577	.7618	.2229	.754	2.490	.7513	.2225	.737
2.442	.7494	.2185	.712	2.349	.7327	.2129	.683
2.291	.7190	.2066	.658	2.198	.6923	.1974	.628
2.113	.6791	.1900	.591	2.064	.6703	.1867	.575
1.976	.6577	.1812	.544	1.912	.6505	.1794	.527
1.823	.6416	.1746	.496	1.773	.6457	.1751	.481
1.699	.6416	.1737	.460	1.631	.6423	.1734	.440
1.559	.6381	.1719	.420	1.487	.6451	.1753	.404
1.419	.6441	.1743	.384	1.348	.6468	.1755	.366
1.278	.6421	.1670	.332	1.205	.6440	.1657	.310
1.136	.6431	.1665	.294	1.064	.6502	.1698	.278
.987	.6502	.1705	.259	.920	.6537	.1744	.245
.868	.6552	.1738	.230	.792	.6557	.1764	.213
.719	.6513	.1764	.195				

$$\beta_{0.75R} = 48^\circ$$

Test C-3				Test C-4			
V/nD	C <sub>P</sub>	C <sub>T</sub>	η	V/nD	C <sub>P</sub>	C <sub>T</sub>	η
2.634	0.2033	0.0563	0.729	2.655	0.1974	0.0552	0.742
2.540	.2483	.0797	.816	2.600	.2199	.0657	.775
2.432	.2953	.1008	.830	2.507	.2627	.0841	.803
2.335	.3380	.1229	.849	2.400	.3071	.1050	.821
2.232	.3771	.1430	.846	2.305	.3538	.1290	.841
2.136	.4027	.1602	.850	2.202	.3913	.1521	.859
2.037	.4097	.1698	.844	2.095	.4095	.1650	.844
1.932	.4073	.1762	.836	2.006	.4111	.1725	.842
1.839	.4087	.1828	.823	1.904	.4117	.1796	.831
1.740	.4081	.1886	.804	1.801	.4107	.1855	.813
1.639	.4141	.1947	.771	1.670	.4138	.1926	.777
1.531	.4169	.1929	.708	1.599	.4186	.1960	.749
1.437	.4149	.1884	.653	1.501	.4184	.1919	.688
1.340	.4153	.1869	.603	1.396	.4165	.1876	.629
1.237	.4184	.1869	.552	1.296	.4196	.1877	.580
1.139	.4249	.1900	.509	1.196	.4247	.1895	.534
1.040	.4334	.1943	.466	1.092	.4324	.1931	.488
.942	.4435	.1985	.422	.997	.4415	.1970	.445
.843	.4516	.2021	.377	.894	.4490	.2003	.399
.749	.4580	.2043	.334	.793	.4566	.2031	.353
.643	.4654	.2076	.287	.698	.4637	.2062	.311
.552	.4724	.2101	.246	.614	.4719	.2092	.272
				.500	.4779	.2125	.223

TABLE 4.- FORCE TEST DATA; MODEL 4 - Continued

$\beta_{0.75R} = 37^\circ$							
Test C-5				Test C-6			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
1.763	0.1121	0.0500	0.788	1.807	0.0972	0.0416	0.773
1.687	.1404	.0684	.822	1.726	.1264	.0600	.819
1.620	.1685	.0898	.863	1.657	.1524	.0775	.843
1.554	.1937	.1066	.855	1.584	.1816	.0971	.847
1.478	.2192	.1268	.855	1.516	.2073	.1172	.857
1.405	.2345	.1423	.853	1.441	.2276	.1354	.857
1.336	.2358	.1488	.843	1.369	.2355	.1460	.849
1.262	.2363	.1556	.831	1.298	.2356	.1519	.837
1.188	.2378	.1623	.811	1.223	.2367	.1582	.817
1.115	.2415	.1697	.784	1.154	.2391	.1661	.802
1.042	.2483	.1776	.745	1.077	.2431	.1735	.769
.974	.2548	.1819	.696	1.004	.2479	.1784	.723
.899	.2635	.1822	.622	.939	.2629	.1840	.657
.828	.2695	.1828	.562	.865	.2654	.1821	.594
.756	.2766	.1869	.511	.794	.2715	.1841	.538
.684	.2852	.1916	.459	.719	.2805	.1892	.485
.610	.2936	.1973	.410	.647	.2899	.1946	.434
.542	.3006	.2010	.362	.575	.2961	.1986	.386
.472	.3076	.2057	.315	.507	.3041	.2043	.341
.395	.3145	.2100	.264	.435	.3112	.2081	.291
				.369	.3172	.2130	.248

 $\beta_{0.75R} = 27^\circ$ 

Test C-7				Test C-8			
1.272	0.0468	0.0258	0.701	1.245	0.0559	0.0323	0.719
1.206	.0682	.0432	.764	1.185	.0747	.0508	.806
1.153	.0834	.0598	.826	1.123	.0931	.0690	.832
1.092	.1023	.0780	.833	1.064	.1097	.0856	.830
1.020	.1202	.0980	.832	1.002	.1254	.1040	.831
.962	.1276	.1086	.819	.942	.1374	.1198	.821
.908	.1411	.1264	.814	.880	.1438	.1320	.808
.849	.1443	.1356	.798	.819	.1438	.1386	.789
.786	.1437	.1421	.778	.758	.1433	.1441	.762
.725	.1435	.1473	.745	.698	.1441	.1506	.730
.670	.1447	.1553	.719	.636	.1452	.1575	.690
.605	.1475	.1624	.666	.577	.1489	.1663	.644
.542	.1526	.1707	.606	.515	.1546	.1726	.575
.483	.1588	.1757	.535	.456	.1621	.1781	.501
.427	.1658	.1786	.460	.397	.1698	.1806	.423
.363	.1736	.1803	.377	.335	.1761	.1818	.346
.288	.1814	.1842	.292				

TABLE 4.— FORCE TEST DATA; MODEL 4 — Concluded

$\beta_{0.75R} = 19^\circ$							
Test C-9				Test C-10			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
0.901	0.0340	0.0229	0.607	0.881	0.3078	0.0292	0.681
.853	.0454	.0387	.727	.830	.0500	.0461	.765
.804	.0572	.0550	.773	.780	.0611	.0608	.776
.753	.0666	.0686	.776	.732	.0707	.0752	.778
.704	.0757	.0836	.777	.679	.0783	.0888	.770
.653	.0812	.0966	.777	.628	.0846	.1019	.757
.604	.0871	.1072	.743	.584	.0903	.1142	.738
.554	.0904	.1174	.719	.531	.0914	.1211	.704
.503	.0912	.1245	.687	.480	.0910	.1277	.673
.452	.0916	.1310	.646	.431	.0915	.1335	.629
.404	.0914	.1380	.610	.379	.0914	.1409	.585
.351	.0910	.1439	.554	.329	.0914	.1457	.525
.304	.0915	.1475	.491	.272	.0921	.1512	.446
.236	.0915	.1552	.400	.209	.0916	.1583	.361
.185	.0920	.1608	.323				
$\beta_{0.75R} = 12^\circ$							
Test C-11				Test C-12			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
0.579	0.0295	0.0278	0.546	0.600	0.0273	0.0221	0.486
.542	.0345	.0389	.611	.565	.0326	.0338	.586
.506	.0398	.0506	.643	.522	.0380	.0458	.628
.467	.0447	.0617	.644	.482	.0420	.0565	.647
.424	.0475	.0722	.645	.442	.0463	.0675	.644
.387	.0504	.0808	.620	.402	.0494	.0763	.620
.346	.0524	.0893	.590	.365	.0519	.0854	.599
.302	.0539	.0983	.551	.321	.0534	.0941	.566
.262	.0543	.1047	.505	.283	.0548	.1017	.525
.220	.0551	.1112	.445	.247	.0554	.1072	.479
				.209	.0552	.1122	.426



TABLE 5. - FORCE TEST DATA; MODEL 5

$\beta_{0.75R} = 60^\circ$							
Test F-1				Test F-2			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
3.632	0.7497	0.1574	0.763	3.678	0.7384	0.1535	0.765
3.474	.7886	.1760	.775	3.534	.7935	.1753	.781
3.342	.8285	.1981	.799	3.410	.8208	.1887	.784
3.196	.8021	.2015	.803	3.266	.8204	.2004	.798
3.049	.7728	.2024	.799	3.131	.7883	.2021	.803
2.906	.7533	.2062	.795	2.982	.7644	.2051	.800
2.767	.7434	.2109	.785	2.840	.7506	.2077	.786
2.626	.7352	.2155	.770	2.699	.7413	.2137	.778
2.472	.7090	.2079	.725	2.548	.7300	.2149	.750
2.352	.7082	.2055	.682	2.400	.7153	.2091	.702
2.204	.6764	.1903	.620	2.263	.6878	.1960	.645
2.060	.6479	.1769	.562	2.120	.6576	.1832	.591
1.919	.6340	.1696	.513	1.970	.6350	.1719	.533
1.780	.6247	.1651	.470	1.836	.6270	.1673	.490
1.636	.6205	.1600	.422	1.691	.6221	.1608	.437
1.494	.6096	.1455	.357	1.558	.6134	.1518	.386
1.348	.6112	.1427	.315	1.415	.6064	.1418	.331
1.209	.6220	.1455	.283	1.275	.6148	.1431	.297
1.069	.6308	.1496	.254	1.141	.6269	.1475	.268
.922	.6385	.1562	.226	.989	.6343	.1535	.239
.783	.6420	.1624	.198	.868	.6384	.1581	.215
				.713	.6404	.1649	.184
$\beta_{0.75R} = 48^\circ$							
Test F-3				Test F-4			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
2.694	0.1238	0.0293	0.638	2.547	0.2147	0.0666	0.790
2.631	.1678	.0436	.684	2.437	.2683	.0886	.805
2.538	.2342	.0737	.799	2.350	.3081	.1093	.834
2.392	.2913	.1000	.821	2.244	.3569	.1344	.845
2.314	.3201	.1145	.828	2.142	.3852	.1516	.843
2.222	.3656	.1390	.845	2.046	.3907	.1616	.846
2.116	.3875	.1557	.850	1.947	.3917	.1675	.833
2.016	.3906	.1642	.847	1.839	.3930	.1756	.822
1.910	.3916	.1704	.831	1.748	.3961	.1822	.804
1.811	.3945	.1784	.819	1.651	.4024	.1881	.772
1.708	.3998	.1851	.791	1.549	.4067	.1881	.716
1.616	.4067	.1899	.755	1.450	.4053	.1833	.656
1.508	.4069	.1864	.691	1.342	.4114	.1836	.599
1.405	.4066	.1828	.631	1.245	.4160	.1847	.553
1.302	.4088	.1824	.581	1.149	.4191	.1857	.509
1.201	.4150	.1843	.533	1.050	.4278	.1888	.463
1.101	.4253	.1873	.485	.946	.4365	.1911	.414
1.000	.4335	.1902	.439	.850	.4395	.1924	.372
.900	.4413	.1923	.392	.748	.4528	.1941	.321
.801	.4484	.1932	.345	.649	.4599	.1957	.276
.701	.4551	.1953	.301	.562	.4645	.1968	.238
.609	.4596	.1958	.259				
.514	.4679	.1985	.218				

TABLE 5.— FORCE TEST DATA; MODEL 5 — Continued

$\beta_{0.75R} = 37^\circ$							
Test F-5				Test F-6			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
1.779	0.0884	0.0357	0.718	1.798	0.0802	0.0304	0.682
1.704	.1201	.0559	.793	1.734	.1077	.0479	.771
1.630	.1506	.0771	.834	1.661	.1386	.0676	.810
1.552	.1811	.0987	.847	1.591	.1692	.0903	.849
1.483	.2074	.1195	.854	1.515	.1957	.1109	.859
1.406	.2212	.1341	.852	1.442	.2174	.1290	.856
1.337	.2226	.1398	.840	1.371	.2219	.1375	.850
1.262	.2244	.1468	.826	1.292	.2229	.1439	.834
1.189	.2290	.1557	.808	1.222	.2269	.1518	.818
1.119	.2341	.1637	.782	1.158	.2305	.1587	.797
1.046	.2427	.1725	.743	1.085	.2375	.1680	.767
.973	.2507	.1772	.688	1.012	.2452	.1748	.721
.899	.2575	.1770	.618	.940	.2547	.1776	.655
.827	.2646	.1786	.558	.866	.2616	.1775	.588
.756	.2724	.1820	.505	.794	.2675	.1790	.531
.683	.2808	.1859	.452	.720	.2750	.1828	.479
.611	.2890	.1903	.402	.647	.2855	.1881	.426
.541	.2970	.1944	.354	.576	.2931	.1921	.378
.469	.3047	.1984	.305	.510	.3003	.1958	.333
.397	.3102	.2018	.258	.435	.3058	.1991	.283
				.341	.3129	.2029	.221
$\beta_{0.75R} = 27^\circ$							
Test F-7				Test F-8			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
1.285	0.0320	0.0122	0.488	1.239	0.0468	0.0253	0.670
1.223	.0516	.0307	.728	1.177	.0696	.0459	.776
1.160	.0733	.0497	.787	1.125	.0851	.0624	.825
1.098	.0921	.0696	.830	1.063	.1043	.0820	.836
1.039	.1088	.0869	.829	1.000	.1207	.1001	.829
.976	.1244	.1055	.828	.936	.1317	.1160	.824
.914	.1346	.1209	.821	.875	.1360	.1262	.812
.854	.1377	.1285	.797	.812	.1358	.1318	.788
.793	.1355	.1342	.785	.754	.1366	.1386	.765
.730	.1365	.1409	.754	.693	.1385	.1457	.729
.669	.1387	.1485	.716	.633	.1406	.1533	.690
.610	.1419	.1561	.671	.572	.1462	.1620	.634
.546	.1467	.1634	.608	.513	.1505	.1666	.568
.486	.1530	.1692	.537	.454	.1576	.1719	.495
.424	.1611	.1727	.455	.394	.1652	.1739	.415
.372	.1685	.1748	.386	.332	.1729	.1762	.338
.294	.1766	.1784	.297				

TABLE 5.- FORCE TEST DATA; MODEL 5 - Concluded

$\beta_{0.75R} = 19^\circ$							
Test F-9				Test F-10			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
0.884	0.0327	0.0232	0.627	0.897	0.0279	0.0172	0.553
.833	.0462	.0413	.745	.850	.0400	.0338	.718
.784	.0572	.0563	.772	.804	.0514	.0494	.773
.731	.0664	.0715	.787	.755	.0607	.0632	.786
.680	.0745	.0852	.778	.705	.0700	.0773	.778
.629	.0817	.0987	.760	.652	.0771	.0916	.775
.579	.0853	.1094	.742	.600	.0827	.1037	.752
.528	.0857	.1162	.716	.551	.0846	.1121	.730
.478	.0863	.1225	.678	.502	.0849	.1184	.700
.427	.0860	.1285	.638	.452	.0850	.1247	.663
.379	.0861	.1349	.594	.398	.0854	.1311	.611
.327	.0855	.1398	.535	.352	.0847	.1362	.566
.277	.0860	.1449	.467	.300	.0846	.1415	.502
.228	.0867	.1504	.396	.259	.0850	.1453	.443
				.201	.0865	.1516	.352

$\beta_{0.75R} = 12^\circ$							
Test F-11				Test F-12			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
0.602	0.0238	0.0179	0.453	0.580	0.0267	0.0243	0.528
.563	.0294	.0300	.574	.543	.0315	.0349	.601
.520	.0348	.0418	.625	.501	.0368	.0475	.647
.483	.0389	.0526	.653	.460	.0410	.0582	.653
.443	.0429	.0633	.654	.420	.0447	.0691	.649
.402	.0465	.0734	.635	.384	.0476	.0779	.628
.362	.0486	.0818	.609	.344	.0496	.0866	.600
.322	.0505	.0902	.575	.306	.0505	.0930	.564
.283	.0509	.0966	.537	.260	.0513	.1006	.510
.249	.0513	.1018	.494	.216	.0515	.1070	.449
.209	.0516	.1073	.435				

TABLE 6.- FORCE TEST DATA; MODEL 6

$\beta_{0.75R} = 60^\circ$							
Test B-1				Test B-2			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
3.695	0.6553	0.1309	0.739	3.603	0.6988	0.1501	0.773
3.577	.7116	.1547	.779	3.448	.7518	.1727	.792
3.428	.7538	.1757	.800	3.303	.7641	.1875	.811
3.279	.7619	.1867	.805	3.161	.7400	.1889	.807
3.123	.7401	.1928	.814	3.029	.7178	.1902	.803
3.009	.7189	.1928	.808	2.886	.6990	.1940	.801
2.863	.7021	.1955	.797	2.749	.6914	.1981	.788
2.721	.6879	.1982	.783	2.606	.6843	.2017	.768
2.575	.6813	.2025	.766	2.451	.6734	.1991	.725
2.425	.6774	.1977	.709	2.309	.6583	.1849	.649
2.289	.6528	.1831	.641	2.178	.6247	.1679	.585
2.145	.6173	.1627	.567	2.036	.5882	.1508	.522
2.001	.5850	.1495	.511	1.897	.5646	.1416	.476
1.836	.5641	.1398	.456	1.760	.5557	.1367	.433
1.714	.5599	.1390	.425	1.613	.5584	.1363	.394
1.564	.5632	.1357	.378	1.473	.5594	.1318	.347
1.414	.5650	.1321	.330	1.335	.5701	.1333	.312
1.288	.5762	.1363	.304	1.183	.5816	.1381	.281
1.140	.5909	.1416	.273	1.060	.5859	.1419	.257
1.016	.5940	.1448	.248	.904	.5869	.1444	.222
.858	.5963	.1476	.212	.775	.5897	.1459	.192
.714	.5987	.1492	.178				
$\beta_{0.75} = 48^\circ$							
Test B-3				Test B-4			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
2.623	0.1562	0.0414	0.695	2.539	0.1916	0.0567	0.751
2.588	.1736	.0485	.723	2.460	.2390	.0782	.805
2.490	.2152	.0684	.791	2.328	.2846	.1015	.830
2.386	.2586	.0876	.808	2.226	.3322	.1267	.848
2.295	.3016	.1103	.839	2.142	.3635	.1452	.855
2.186	.3491	.1350	.845	2.038	.3710	.1552	.853
2.078	.3686	.1503	.847	1.934	.3708	.1617	.843
1.984	.3709	.1595	.853	1.827	.3708	.1677	.826
1.892	.3709	.1642	.838	1.730	.3705	.1723	.805
1.789	.3709	.1704	.823	1.633	.3769	.1782	.772
1.684	.3748	.1757	.789	1.529	.3824	.1762	.705
1.584	.3812	.1794	.745	1.431	.3841	.1708	.636
1.483	.3823	.1737	.674	1.333	.3828	.1657	.577
1.386	.3856	.1687	.606	1.231	.3825	.1629	.524
1.291	.3826	.1642	.553	1.132	.3865	.1640	.480
1.189	.3864	.1634	.506	1.040	.3942	.1659	.438
1.089	.3904	.1650	.460	.945	.3991	.1669	.395
.992	.3956	.1650	.414	.843	.4080	.1686	.348
.892	.4016	.1667	.370	.743	.4157	.1713	.306
.793	.4113	.1694	.327	.641	.4262	.1751	.263
.697	.4197	.1725	.287	.534	.4362	.1798	.220
.599	.4303	.1770	.246				
.511	.4373	.1803	.211				

TABLE 6. -- FORCE TEST DATA; MODEL 6 - Continued

$\beta_{0.75R} = 37^\circ$							
Test B-5				Test B-6			
V/nd	$C_P$	$C_T$	$\eta$	V/nd	$C_P$	$C_T$	$\eta$
1.802	0.0696	0.0240	0.552	1.744	0.0941	0.0401	0.743
1.730	.0960	.0419	.756	1.675	.1169	.0555	.795
1.650	.1270	.0643	.835	1.610	.1400	.0721	.830
1.591	.1513	.0800	.841	1.542	.1686	.0931	.851
1.497	.1813	.1024	.846	1.469	.1939	.1119	.848
1.435	.2031	.1212	.856	1.396	.2090	.1272	.850
1.363	.2107	.1312	.849	1.326	.2104	.1341	.845
1.296	.2123	.1381	.843	1.250	.2125	.1409	.829
1.217	.2150	.1448	.820	1.177	.2138	.1476	.813
1.150	.2176	.1520	.803	1.107	.2185	.1546	.783
1.063	.2222	.1583	.757	1.037	.2260	.1620	.743
1.002	.2297	.1637	.714	.961	.2319	.1641	.680
.928	.2348	.1631	.645	.893	.2381	.1633	.612
.861	.2416	.1627	.579	.819	.2453	.1632	.545
.789	.2495	.1634	.517	.749	.2533	.1652	.488
.715	.2587	.1666	.460	.677	.2618	.1683	.435
.643	.2643	.1693	.412	.605	.2678	.1709	.386
.573	.2707	.1727	.366	.537	.2720	.1737	.343
.494	.2762	.1755	.314	.466	.2773	.1759	.296
.429	.2809	.1775	.271	.392	.2837	.1791	.248
.378	.2839	.1797	.239				

$\beta_{0.75R} = 27^\circ$							
Test B-7				Test B-8			
V/nd	$C_P$	$C_T$	$\eta$	V/nd	$C_P$	$C_T$	$\eta$
1.272	0.0282	0.0102	0.507	1.246	0.0374	0.0177	0.590
1.211	.0472	.0272	.697	1.187	.0547	.0347	.753
1.149	.0650	.0445	.788	1.127	.0722	.0507	.791
1.088	.0826	.0624	.822	1.063	.0879	.0684	.827
1.029	.0980	.0792	.831	1.002	.1048	.0872	.834
.967	.1139	.0980	.832	.939	.1196	.1060	.832
.907	.1246	.1132	.824	.879	.1258	.1173	.820
.846	.1264	.1209	.809	.838	.1265	.1241	.812
.784	.1267	.1266	.782	.755	.1271	.1298	.771
.726	.1276	.1329	.756	.695	.1274	.1359	.741
.665	.1288	.1392	.719	.637	.1294	.1419	.699
.608	.1316	.1454	.672	.577	.1338	.1486	.641
.546	.1361	.1507	.605	.514	.1388	.1524	.564
.484	.1416	.1531	.523	.455	.1446	.1542	.485
.421	.1464	.1548	.445	.399	.1491	.1564	.419
.366	.1513	.1572	.380	.326	.1565	.1604	.334
.286	.1597	.1621	.290				

TABLE 6.- FORCE TEST DATA; MODEL 6 - Concluded

$\beta_{0.75R} = 19^\circ$							
Test B-9				Test B-10			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
0.874	0.0232	0.0096	0.364	0.872	0.0309	0.0193	0.545
.850	.0336	.0257	.652	.827	.0397	.0340	.709
.804	.0431	.0406	.757	.781	.0485	.0470	.757
.751	.0539	.0549	.765	.722	.0576	.0632	.793
.702	.0628	.0704	.786	.680	.0665	.0756	.773
.652	.0711	.0848	.778	.631	.0742	.0894	.760
.602	.0763	.0967	.762	.580	.0768	.0997	.753
.545	.0778	.1035	.724	.530	.0782	.1071	.724
.503	.0786	.1104	.706	.477	.0784	.1135	.691
.452	.0796	.1169	.663	.428	.0791	.1201	.649
.403	.0804	.1231	.617	.389	.0793	.1249	.612
.349	.0809	.1284	.554	.328	.0793	.1305	.540
.303	.0811	.1334	.499	.287	.0807	.1346	.478
.264	.0822	.1367	.440	.243	.0822	.1386	.411
.195	.0828	.1420	.334				

$\beta_{0.75R} = 12^\circ$							
Test B-13				Test B-14			
.605	0.0186	0.0070	0.228	0.578	0.0224	0.0161	0.416
.563	.0238	.0194	.458	.537	.0267	.0276	.555
.525	.0284	.0302	.558	.502	.0312	.0381	.613
.484	.0328	.0418	.618	.462	.0356	.0495	.642
.444	.0372	.0533	.637	.424	.0396	.0607	.650
.404	.0408	.0640	.634	.380	.0426	.0703	.627
.363	.0425	.0726	.621	.341	.0441	.0778	.601
.324	.0440	.0799	.587	.305	.0447	.0839	.573
.282	.0446	.0861	.545	.257	.0455	.0914	.517
.246	.0450	.0913	.499	.211	.0456	.0971	.449
.210	.0454	.0973	.451				

TABLE 7.- FORCE TEST DATA; MODEL 7

$\beta_{0.75R} = 60^\circ$							
Test A-1				Test A-2			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
3.617	0.6214	0.1353	0.788	3.677	0.6023	0.1292	0.789
3.497	.6497	.1494	.804	3.563	.6390	.1444	.805
3.342	.6641	.1595	.803	3.408	.6570	.1569	.814
3.206	.6795	.1715	.809	3.265	.6756	.1684	.814
3.060	.6909	.1810	.802	3.113	.6868	.1790	.811
2.922	.6957	.1920	.806	2.992	.6956	.1890	.813
2.771	.6960	.1971	.785	2.840	.6964	.1947	.794
2.628	.6932	.1991	.755	2.699	.6958	.1991	.772
2.485	.6822	.1898	.692	2.546	.6904	.1977	.729
2.343	.6325	.1557	.577	2.417	.6634	.1797	.655
2.194	.5785	.1356	.514	2.289	.6092	.1495	.562
2.038	.5515	.1201	.444	2.134	.5669	.1301	.490
1.893	.5358	.1145	.405	1.958	.5416	.1160	.419
1.756	.5368	.1136	.372	1.824	.5348	.1136	.387
1.613	.5408	.1147	.342	1.677	.5356	.1131	.354
1.493	.5545	.1183	.319	1.552	.5443	.1157	.330
1.352	.5711	.1243	.294	1.421	.5674	.1232	.309
1.210	.5850	.1288	.266	1.277	.5712	.1266	.283
1.062	.5834	.1321	.240	1.133	.5833	.1312	.255
.914	.5905	.1391	.215	.998	.5874	.1353	.230
.787	.5922	.1432	.190	.862	.5928	.1422	.207
				.707	.5918	.1436	.172

 $\beta_{0.75R} = 48^\circ$ 

Test A-3				Test A-4			
2.559	0.1934	0.0613	0.811	2.661	0.1452	0.0416	0.762
2.455	.2358	.0815	.848	2.631	.1617	.0472	.768
2.347	.2774	.1024	.866	2.528	.2035	.0671	.834
2.254	.3009	.1163	.871	2.420	.2444	.0854	.846
2.157	.3203	.1293	.871	2.322	.2834	.1059	.867
2.056	.3351	.1405	.862	2.221	.3059	.1199	.871
1.950	.3496	.1522	.849	2.127	.3216	.1315	.870
1.856	.3602	.1617	.833	2.024	.3386	.1432	.856
1.752	.3701	.1704	.807	1.921	.3502	.1547	.849
1.652	.3807	.1743	.756	1.821	.3625	.1646	.827
1.551	.3839	.1695	.685	1.712	.3714	.1717	.791
1.447	.3796	.1626	.620	1.615	.3827	.1750	.739
1.343	.3784	.1587	.563	1.513	.3825	.1666	.659
1.245	.3769	.1531	.506	1.412	.3778	.1617	.604
1.153	.3834	.1508	.454	1.309	.3781	.1574	.545
1.054	.3878	.1540	.419	1.205	.3800	.1523	.483
.954	.3998	.1574	.376	1.106	.3851	.1531	.440
.852	.4104	.1624	.337	1.008	.3938	.1556	.398
.759	.4203	.1668	.301	.905	.4058	.1606	.358
.653	.4295	.1707	.360	.806	.4142	.1646	.320
.558	.4362	.1736	.222	.711	.4241	.1691	.283
				.599	.4323	.1727	.239
				.519	.4373	.1754	.208

TABLE 7.— FORCE TEST DATA; MODEL 7 — Continued

$\beta_{0.75R} = 37^\circ$							
Test A-5				Test A-6			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
1.762	0.0799	0.0363	0.801	1.813	0.0608	0.0240	0.715
1.700	.1048	.0530	.860	1.743	.0887	.0419	.823
1.621	.1327	.0711	.868	1.666	.1142	.0593	.865
1.549	.1570	.0897	.834	1.603	.1368	.0757	.887
1.479	.1704	.1021	.886	1.527	.1623	.0933	.878
1.409	.1828	.1135	.875	1.461	.1739	.1050	.882
1.333	.1948	.1258	.861	1.387	.1870	.1168	.866
1.263	.2018	.1347	.843	1.309	.1966	.1273	.847
1.191	.2090	.1435	.817	1.234	.2047	.1382	.833
1.118	.2147	.1509	.785	1.160	.2118	.1474	.807
1.045	.2234	.1561	.730	1.084	.2185	.1541	.764
.971	.2322	.1554	.650	1.010	.2279	.1564	.693
.898	.2385	.1555	.586	.940	.2356	.1564	.624
.827	.2459	.1556	.523	.866	.2436	.1564	.556
.755	.2536	.1568	.467	.797	.2505	.1572	.500
.682	.2609	.1598	.418	.726	.2573	.1582	.446
.611	.2670	.1624	.372	.654	.2649	.1613	.398
.539	.2722	.1644	.325	.578	.2712	.1649	.351
.470	.2790	.1688	.284	.509	.2758	.1674	.309
.394	.2839	.1716	.238	.434	.2818	.1710	.263
				.376	.2865	.1728	.226
$\beta_{0.75R} = 27^\circ$							
Test A-7				Test A-8			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
1.283	.0247	.0112	.582	1.236	.0368	.0224	.753
1.221	.0444	.0278	.765	1.178	.0543	.0379	.821
1.163	.0606	.0433	.831	1.116	.0707	.0542	.855
1.102	.0758	.0589	.856	1.060	.0837	.0679	.860
1.040	.0905	.0749	.861	.996	.0972	.0836	.856
.975	.1031	.0899	.850	.936	.1075	.0969	.844
.914	.1111	.1018	.837	.875	.1132	.1071	.823
.853	.1159	.1109	.816	.814	.1183	.1165	.803
.793	.1209	.1202	.788	.756	.1211	.1242	.776
.731	.1237	.1279	.756	.695	.1245	.1321	.737
.673	.1263	.1352	.720	.635	.1265	.1379	.692
.611	.1300	.1407	.661	.573	.1336	.1421	.610
.549	.1379	.1429	.569	.513	.1421	.1417	.511
.489	.1477	.1439	.476	.456	.1493	.1444	.441
.428	.1546	.1481	.410	.392	.1570	.1490	.372
.367	.1625	.1531	.346	.343	.1629	.1526	.321
.316	.1678	.1562	.294				

TABLE 7.— FORCE TEST DATA; MODEL 7 — Concluded

$\beta_{0.75R} = 19^\circ$							
Test A-9				Test A-10			
V/nD	$C_P$	$C_T$	$\eta$	V/nD	$C_P$	$C_T$	$\eta$
0.880	0.0219	0.0150	0.606	0.908	0.0147	0.0060	0.369
.830	.0323	.0292	.748	.860	.0262	.0202	.665
.780	.0422	.0427	.790	.807	.0359	.0339	.762
.732	.0492	.0551	.819	.751	.0456	.0489	.806
.679	.0564	.0666	.802	.711	.0523	.0586	.797
.629	.0618	.0782	.796	.658	.0584	.0708	.798
.581	.0669	.0885	.768	.607	.0643	.0828	.782
.530	.0703	.0979	.738	.557	.0682	.0931	.760
.478	.0726	.1061	.699	.504	.0715	.1022	.720
.428	.0736	.1121	.651	.455	.0733	.1090	.677
.377	.0735	.1169	.599	.403	.0739	.1146	.625
.328	.0744	.1228	.540	.355	.0741	.1197	.573
.294	.0756	.1248	.485	.307	.0747	.1239	.508
.271	.0769	.1260	.445	.257	.0780	.1258	.415
.227	.0807	.1284	.361	.197	.0840	.1307	.306

$\beta_{0.75R} = 12^\circ$							
Test A-11				Test A-12			
.600	.0156	.0092	.353	.580	.0186	.0142	.444
.560	.0205	.0194	.528	.541	.0231	.0243	.570
.519	.0247	.0294	.618	.500	.0271	.0340	.628
.489	.0287	.0371	.632	.460	.0305	.0428	.645
.439	.0317	.0480	.666	.419	.0336	.0524	.653
.401	.0348	.0568	.654	.383	.0360	.0599	.637
.361	.0368	.0647	.635	.343	.0380	.0681	.614
.325	.0388	.0719	.603	.308	.0397	.0745	.579
.283	.0402	.0791	.557	.260	.0412	.0833	.526
.247	.0409	.0843	.510	.235	.0412	.0862	.493
.202	.0415	.0910	.444	.213	.0416	.0901	.460

TABLE 8.- WAKE SURVEY DATA; MODEL 1

$$[\beta_{0.75R} = 12^\circ]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V}{nD}$						
x	0.608		0.568		0.526	
0.20	0.015	0.002	0.018	0.002	0.022	0.002
.35	.048	.006	.058	.007	.068	.008
.48	.070	.008	.086	.010	.101	.011
.60	.070	.009	.088	.010	.105	.012
.71	.043	.006	.062	.008	.083	.010
.81	-.004	.003	.014	.004	.033	.006
.89	-.034	0	-.028	.001	-.012	.003
.95	-.051	.002	-.043	0	-.032	.001
1.00	0	.003	-.002	.003	-.001	.002
1.05	0	0	0	0	0	0
$\frac{V}{nD}$						
x	0.488		0.407		0.330	
0.20	0.024	0.002	0.029	0.003	0.032	0.003
.35	.076	.008	.089	.009	.098	.010
.48	.112	.012	.135	.014	.151	.015
.60	.120	.013	.151	.015	.177	.017
.71	.099	.011	.132	.013	.162	.016
.81	.048	.007	.079	.009	.104	.010
.89	0	.004	.021	.005	.027	.005
.95	-.022	.001	-.008	.001	-.002	0
1.00	-.001	.001	-.002	0	-.001	0
1.05	0	.001	0	0	0	0



TABLE 8.- WAKE SURVEY DATA; MODEL 1 - Continued

$$\left[ \beta_{0.75R} = 19^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/ND}{x}$	0.909		0.856		0.810		0.702	
0.20	0.005	0.001	0.012	0.002	0.015	0.002	0.022	0.003
.35	.034	.006	.045	.007	.056	.008	.082	.011
.48	.060	.010	.078	.012	.096	.014	.135	.019
.60	.069	.012	.095	.015	.116	.017	.163	.022
.71	.053	.010	.081	.014	.108	.017	.162	.022
.81	.019	.006	.480	.009	.073	.012	.125	.017
.89	-.018	.001	.008	.004	.029	.006	.071	.011
.95	-.036	0	-.016	.002	-.005	.003	.022	.005
1.00	-.006	.004	-.004	.003	-.005	.001	-.002	.001
1.05	-.003	0	-.002	0	-.001	0	-.002	.001
$\frac{V/ND}{x}$	0.604		0.505		0.406		0.311	
0.20	0.028	0.004	0.033	0.004	0.038	0.004	0.041	0.004
.35	.099	.013	.107	.013	.114	.013	.119	.013
.48	.160	.021	.171	.021	.180	.021	.189	.021
.60	.199	.026	.221	.027	.229	.026	.240	.027
.71	.206	.026	.241	.029	.258	.029	.265	.029
.81	.171	.021	.212	.025	.244	.026	.246	.025
.89	.106	.014	.146	.017	.174	.020	.081	.016
.95	.014	.005	-.002	.003	-.004	.002	.006	.001
1.00	-.001	.001	-.001	.001	.001	.001	.002	0
1.05	-.001	.001	0	.001	0	0	.001	0



TABLE 8.— WAKE SURVEY DATA; MODEL 1 — Continued

$$\left[ \beta_{0.75R} = 27^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.293		1.232		1.169		1.108	
0.20	0.003	0	0.002	0.001	0.009	0.002	0.015	0.003
.35	.021	0.005	.033	.008	.044	.010	.058	.012
.48	.047	.011	.068	.015	.086	.018	.111	.022
.60	.066	.015	.094	.020	.118	.025	.148	.029
.71	.062	.015	.093	.021	.120	.026	.150	.031
.81	.038	.010	.071	.017	.097	.022	.130	.027
.89	.001	.005	.037	.010	.060	.015	.085	.018
.95	-.012	.002	.008	.005	.021	.008	.038	.010
1.00	-.006	0	-.008	-.001	-.011	0	-.011	0
1.05	-.003	0	-.002	0	-.006	.001	-.004	.001
$\frac{V/nD}{x}$	1.037		0.917		0.794		0.613	
0.20	0.019	0.004	0.024	0.005	0.029	0.005	0.038	0.005
.35	.078	.014	.101	.018	.111	.018	.126	.018
.48	.138	.026	.172	.030	.181	.029	.207	.030
.60	.178	.033	.225	.038	.234	.038	.270	.039
.71	.188	.036	.250	.043	.267	.043	.300	.045
.81	.168	.032	.236	.039	.263	.041	.293	.043
.89	.115	.022	.177	.029	.217	.033	.252	.033
.95	.055	.012	.090	.019	.091	.021	-.004	.010
1.00	-.008	0	.006	.001	-.001	.002	-.003	.002
1.05	-.005	.001	.006	.001	-.002	.002	-.001	.001
$\frac{V/nD}{x}$	0.490		0.372					
0.20	0.045	0.005	0.045	0.006				
.35	.137	.018	.143	.019				
.48	.225	.031	.240	.034				
.60	.299	.044	.335	.050				
.71	.327	.051	.343	.062				
.81	.309	.047	.252	.052				
.89	.261	.035	.099	.044				
.95	-.015	.008	-.007	.008				
1.00	-.002	.002	-.004	.002				
1.05	-.001	.001	-.003	.001				

TABLE 8.— WAKE SURVEY DATA; MODEL 1 — Continued

$$[\beta_{0.75R} = 37^\circ]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.806		1.741		1.670		1.600	
0.20	0.001	0.003	0.004	0.004	0.012	0.005	0.016	0.006
.35	.038	.013	.045	.015	.058	.017	.070	.020
.48	.071	.022	.083	.026	.108	.030	.132	.036
.60	.100	.031	.119	.036	.151	.042	.182	.049
.71	.107	.033	.127	.040	.163	.047	.198	.055
.81	.091	.027	.114	.035	.151	.043	.191	.051
.89	.059	.020	.081	.028	.115	.033	.143	.039
.95	.024	.012	.036	.017	.060	.020	.086	.026
1.00	-.018	-.002	-.019	0	-.018	0	-.016	.001
1.05	-.008	0	-.010	0	-.007	.002	-.006	.001
$\frac{V/nD}{x}$	1.526		1.386		1.160		0.941	
0.20	0.017	0.007	0.018	0.007	0.026	0.008	0.040	0.009
.35	.081	.023	.108	.027	.130	.029	.141	.028
.48	.155	.042	.190	.048	.211	.046	.240	.046
.60	.214	.056	.255	.062	.284	.061	.324	.065
.71	.235	.064	.280	.071	.319	.072	.380	.082
.81	.231	.061	.282	.068	.322	.071	.359	.083
.89	.186	.048	.238	.057	.278	.059	.274	.067
.95	.122	.033	.172	.043	.194	.047	.064	.044
1.00	-.013	.001	-.014	.003	0	.004	-.003	.005
1.05	0	.003	-.006	.004	-.002	.004	-.006	.004
$\frac{V/nD}{x}$	0.725		0.513					
0.20	0.048	0.009	0.049	0.010				
.35	.158	.028	.171	.030				
.48	.273	.050	.313	.058				
.60	.412	.078	.496	.096				
.71	.432	.106	.310	.091				
.81	.238	.070	.200	.067				
.89	.160	.063	.109	.076				
.95	.053	.046	.044	.054				
1.00	-.005	.011	---	.027				
1.05	0	.004	-.001	.008				

TABLE 8.— WAKE SURVEY DATA; MODEL 1 — Continued

$$\left[ \beta_{0.75R} = 48^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	2.643		2.529		2.425		2.325	
0.20	0.010	0.015	0.013	0.016	0.021	0.017	0.024	0.018
.35	.067	.034	.077	.038	.095	.041	.104	.045
.48	.100	.046	.123	.054	.157	.063	.178	.071
.60	.119	.056	.160	.068	.208	.079	.230	.091
.71	.125	.055	.160	.070	.216	.085	.245	.100
.81	.102	.043	.146	.060	.195	.076	.234	.094
.89	.068	.033	.103	.046	.152	.060	.186	.077
.95	.026	.022	.062	.030	.088	.039	.121	.053
1.00	-.027	-.002	-.025	-.003	-.032	0	-.034	.003
1.05	-.012	0	-.011	0	-.010	0	-.013	0
$\frac{V/nD}{x}$	2.227		2.021		1.819		1.621	
0.20	0.028	0.019	0.035	0.019	0.034	0.019	0.033	0.018
.35	.120	.049	.139	.054	.156	.054	.162	.050
.48	.204	.078	.231	.085	.243	.080	.256	.076
.60	.269	.099	.300	.106	.320	.103	.343	.102
.71	.285	.111	.317	.117	.347	.118	.391	.124
.81	.287	.107	.314	.114	.354	.119	.406	.131
.89	.243	.089	.277	.096	.326	.100	.314	.109
.95	.170	.065	.201	.073	.225	.079	.178	.077
1.00	-.019	.005	-.026	.007	-.029	.007	-.021	.007
1.05	-.008	.003	-.010	.004	-.014	.005	-.011	.004
$\frac{V/nD}{x}$	1.512		1.309		1.011		0.709	
0.20	0.036	0.017	0.045	0.016	0.055	0.016	0.047	0.016
.35	.158	.048	.164	.045	.182	.044	.190	.044
.48	.264	.076	.285	.075	.327	.081	.372	.088
.60	.362	.104	.425	.115	.554	.141	.567	.169
.71	.431	.132	.450	.147	.318	.120	.197	.095
.81	.382	.133	.263	.111	.236	.096	.234	.101
.89	.259	.103	.170	.088	.144	.086	.131	.104
.95	.148	.066	.084	.064	.061	.080	.063	.087
1.00	-.009	.008	-.008	.018	.026	.063	.019	.072
1.05	0	.005	-.003	.006	-.009	.016	0	.042

TABLE 8.- WAKE SURVEY DATA; MODEL 1 -- Concluded

$$[\beta_{0.75R} = 60^\circ]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	3.664		3.508		3.357		3.219	
0.20	-0.021	0.060	-0.019	0.058	-0.016	0.053	-0.021	0.053
.35	.185	.142	.200	.140	.204	.137	.194	.134
.48	.258	.185	.297	.188	.310	.190	.301	.187
.60	.323	.200	.371	.217	.398	.221	.391	.220
.71	.322	.200	.364	.213	.390	.230	.387	.228
.81	.273	.163	.337	.188	.387	.208	.369	.212
.89	.216	.132	.275	.150	.315	.173	.319	.179
.95	.110	.095	.165	.106	.235	.128	.240	.134
1.00	-.042	0	-.039	---	.009	.009	-.016	.012
1.05	0	.005	-.030	0	.019	.004	-.017	.012
$\frac{V/nD}{x}$	2.936		2.794		2.648		2.491	
0.20	-0.008	0.047	-0.006	0.050	-0.003	0.044	-0.002	0.041
.35	.209	.125	.206	.117	.195	.110	.177	.100
.48	.315	.169	.309	.159	.304	.154	.292	.146
.60	.406	.203	.412	.196	.406	.193	.395	.188
.71	.418	.220	.418	.218	.430	.215	.439	.217
.81	.411	.213	.417	.215	.433	.218	.430	.222
.89	.362	.179	.349	.178	.358	.187	.334	.185
.95	.257	.135	.256	.135	.256	.140	.218	.129
1.00	-.041	.010	-.049	.012	-.039	.014	-.029	.015
1.05	-.014	.010	-.019	.006	-.017	.011	-.031	.010
$\frac{V/nD}{x}$	2.221		2.078		1.796		1.503	
0.20	0.014	0.039	0.022	0.036	0.041	0.033	0.049	0.030
.35	.186	.091	.180	.086	.195	.080	.186	.075
.48	.316	.136	.314	.132	.358	.134	.386	.136
.60	.442	.188	.474	.193	.547	.210	.536	.223
.71	.454	.221	.409	.212	.309	.174	.181	.178
.81	.339	.203	.255	.173	.191	.147	.233	.147
.89	.255	.155	.175	.136	.117	.119	.120	.113
.95	.155	.099	.097	.092	.046	.110	.039	.116
1.00	-.023	.012	-.037	.019	-.015	.065	.012	.098
1.05	0	.008	-.014	.003	0	.010	-.015	.026
$\frac{V/nD}{x}$	1.215		0.927					
0.20	0.047	0.028	0.017	0.027				
.35	.179	.069	.190	.066				
.48	.411	.137	.440	.142				
.60	.457	.207	.404	.201				
.71	.146	.136	.062	.135				
.81	.281	.160	.213	.154				
.89	.154	.140	.199	.157				
.95	.050	.112	.088	.121				
1.00	.028	.095	.028	.096				
1.05	0	.046	0	.068				

TABLE 9.- WAKE SURVEY DATA; MODEL 2

$$\left[ \beta_{0.75R} = 12^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	0.603		0.567		0.525	
0.20	0.011	0.001	0.014	0.002	0.017	0.002
.35	.041	.005	.050	.006	.058	.007
.48	.063	.007	.076	.008	.088	.010
.60	.066	.008	.080	.009	.096	.010
.71	.042	.006	.059	.007	.078	.009
.81	.004	.003	.022	.004	.039	.006
.89	-.036	.001	-.019	.002	-.003	.003
.95	-.054	0	-.042	0	-.031	.002
1.00	-.006	.011	-.005	.010	-.005	.006
1.05	.002	0	.003	0	0	0
$\frac{V/nD}{x}$	0.488		0.408		0.325	
0.20	0.020	0.020	0.023	0.002	0.028	0.002
.35	.067	.072	.080	.008	.086	.008
.48	.101	.107	.122	.012	.137	.013
.60	.112	.117	.139	.014	.165	.016
.71	.095	.104	.126	.013	.157	.015
.81	.057	.071	.088	.010	.116	.011
.89	.014	.042	.040	.006	.053	.008
.95	-.020	.022	-.006	.001	-.001	0
1.00	0	.028	-.001	0	-.001	0
1.05	0	.004	0	.001	0	0



TABLE 9.— WAKE SURVEY DATA; MODEL 2 — Continued

$$\left[ \beta_{0.75R} = 19^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	0.913		0.857		0.807		0.707	
0.20	-0.004	0	0.003	0.001	0.009	0.002	0.019	0.003
.35	.020	0.004	.034	.005	.047	.007	.070	.010
.48	.046	.008	.066	.010	.089	.013	.118	.016
.60	.060	.011	.085	.013	.109	.016	.149	.020
.71	.048	.009	.078	.013	.103	.016	.153	.021
.81	.024	.006	.054	.010	.081	.013	.133	.018
.89	-.010	.003	.019	.006	.044	.008	.087	.013
.95	-.032	.001	-.012	.004	.006	.005	.037	.073
1.00	-.012	.007	-.008	.004	-.005	.002	-.001	0
1.05	-.005	0	-.002	0	0	.001	0	.001
$\frac{V/nD}{x}$	0.605		0.505		0.406		0.305	
0.20	0.025	0.003	0.030	0.003	0.033	0.003	0.036	0.003
.35	.087	.011	.093	.011	.093	.010	.104	.010
.48	.141	.018	.150	.017	.157	.017	.165	.017
.60	.183	.023	.199	.023	.205	.023	.216	.024
.71	.197	.025	.234	.028	.241	.027	.251	.027
.81	.178	.022	.226	.026	.254	.027	.259	.027
.89	.131	.016	.178	.020	.216	.023	.190	.023
.95	.035	.009	.002	.005	-.009	.004	-.021	.002
1.00	0	.001	0	.001	0	.001	-.002	.001
1.05	0	.001	.001	.001	0	0	0	0

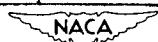


TABLE 9.— WAKE SURVEY DATA; MODEL 2 — Continued

$$\left[ \beta_{0.75R} = 27^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.265		1.218		1.156		1.093	
0.20	-0.013	-0.001	-0.009	-0.003	-0.002	0.001	0.010	0.002
.35	.013	.004	.021	.005	.033	.007	.051	.010
.48	.043	.010	.058	.012	.078	.016	.102	.020
.60	.070	.016	.089	.019	.113	.024	.143	.028
.71	.073	.017	.094	.021	.122	.026	.155	.031
.81	.060	.015	.082	.019	.114	.025	.149	.029
.89	.037	.010	.055	.013	.084	.019	.114	.023
.95	.011	.007	.023	.010	.047	.013	.069	.016
1.00	-.009	0	-.012	0	-.006	0	-.007	.001
1.05	0	0	-.005	0	-.004	.001	-.002	.001
$\frac{V/nD}{x}$	1.031		0.911		0.789		0.615	
0.20	0.018	0.003	0.025	0.005	0.030	0.005	0.034	0.004
.35	.067	.012	.088	.015	.099	.015	.109	.015
.48	.123	.023	.152	.026	.162	.025	.182	.025
.60	.169	.031	.207	.034	.215	.033	.244	.035
.71	.184	.035	.240	.041	.256	.041	.286	.043
.81	.183	.034	.245	.041	.283	.043	.307	.043
.89	.144	.026	.203	.034	.254	.038	.280	.038
.95	.091	.019	.136	.025	.162	.031	.072	.028
1.00	-.003	.001	0	.002	0	.003	-.002	.004
1.05	0	.002	0	.002	0	.002	0	.002
$\frac{V/nD}{x}$	0.484		0.367					
0.20	0.038	0.004	0.041	0.004				
.35	.117	.015	.125	.015				
.48	.197	.027	.223	.031				
.60	.276	.041	.311	.047				
.71	.296	.047	.290	.054				
.81	.304	.045	.271	.051				
.89	.294	.039	.235	.046				
.95	-.072	.023	-.019	.015				
1.00	-.003	.029	-.006	.003				
1.05	.002	.001	0	.001				

TABLE 9.— WAKE SURVEY DATA; MODEL 2 — Continued

$$\left[ \beta_{0.75R} = 37^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.805		1.740		1.669		1.595	
0.20	-0.007	0.001	-0.003	0.002	0.006	0.003	0.012	0.005
.35	.023	.008	.030	.009	.045	.012	.064	.016
.48	.058	.017	.071	.021	.097	.026	.113	.031
.60	.092	.027	.113	.031	.144	.039	.168	.045
.71	.105	.031	.128	.037	.168	.046	.190	.053
.81	.106	.030	.127	.036	.167	.045	.199	.054
.89	.082	.024	.110	.029	.142	.038	.172	.043
.95	.051	.017	.070	.022	.094	.027	.123	.035
1.00	-.010	-.002	-.010	-.001	-.013	.005	-.010	.002
1.05	0	.001	0	0	0	0	0	.003
$\frac{V/nD}{x}$	1.522		1.379		1.230		0.938	
0.20	0.020	0.006	0.027	0.008	0.027	0.008	0.036	0.007
.35	.071	.020	.095	.024	.109	.025	.122	.023
.48	.134	.036	.164	.041	.177	.039	.209	.039
.60	.194	.051	.228	.055	.242	.054	.303	.061
.71	.222	.061	.262	.066	.285	.066	.351	.079
.81	.236	.063	.290	.071	.315	.070	.352	.079
.89	.210	.055	.267	.064	.291	.064	.322	.073
.95	.152	.043	.219	.054	.268	.055	.255	.060
1.00	-.016	.003	-.007	.005	-.002	.006	-.003	.010
1.05	-.006	.003	-.003	.004	-.002	.004	-.004	.004
$\frac{V/nD}{x}$	0.725		0.514					
0.20	0.041	0.007	0.047	0.007				
.35	.138	.023	.146	.023				
.48	.250	.045	.289	.052				
.60	.393	.074	.428	.086				
.71	.350	.081	.287	.066				
.81	.273	.073	.254	.071				
.89	.220	.073	.165	.092				
.95	.098	.065	.072	.070				
1.00	.004	.026	.009	.035				
1.05	0	.004	-.006	.010				

TABLE 9.— WAKE SURVEY DATA; MODEL 2 — Continued

$$\left[ \beta_{0.75R} = 48^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	2.604		2.533		2.434		2.328	
0.20	0.014	0.012	0.017	0.012	0.023	0.014	0.017	0.015
.35	.054	.027	.065	.029	.082	.034	.089	.038
.48	.092	.041	.106	.046	.134	.035	.149	.062
.60	.125	.055	.151	.060	.193	.073	.220	.081
.71	.132	.060	.165	.066	.212	.081	.239	.095
.81	.129	.056	.171	.064	.219	.082	.252	.096
.89	.100	.049	.144	.054	.191	.070	.220	.084
.95	.061	.039	.096	.042	.133	.056	.166	.068
1.00	-.032	0	-.030	0	-.023	0	-.034	.003
1.05	-.022	0	0	0	0	0	-.013	.001
$\frac{V/nD}{x}$	2.232		2.019		1.813		1.613	
0.20	0.019	0.016	0.022	0.016	0.019	0.015	0.024	0.014
.35	.103	.043	.129	.047	.137	.043	.137	.041
.48	.177	.068	.209	.073	.206	.068	.223	.065
.60	.249	.091	.276	.095	.288	.091	.311	.092
.71	.278	.107	.311	.111	.326	.110	.376	.119
.81	.298	.113	.337	.119	.366	.119	.412	.129
.89	.268	.100	.313	.108	.342	.112	.380	.123
.95	.204	.083	.258	.091	.297	.097	.320	.101
1.00	-.035	.006	-.019	.007	-.013	.013	-.012	.015
1.05	-.012	.005	-.007	.007	0	.007	0	.006
$\frac{V/nD}{x}$	1.511		1.308		1.021		0.710	
0.20	0.027	0.013	0.035	0.013	0.048	0.012	0.053	0.013
.35	.136	.040	.146	.038	.158	.036	.160	.036
.48	.230	.065	.255	.066	.309	.075	.358	.085
.60	.336	.096	.419	.110	.511	.132	.457	.137
.71	.401	.125	.381	.123	.292	.093	.243	.101
.81	.389	.131	.307	.111	.298	.103	.323	.120
.89	.321	.117	.230	.099	.204	.102	.200	.118
.95	.245	.093	.114	.085	.065	.092	.079	.100
1.00	-.007	.017	.007	.042	.035	.079	.031	.070
1.05	0	.005	0	.006	-.008	.031	.003	.039

TABLE 9.— WAKE SURVEY DATA; MODEL 2 — Concluded

$$\left[ \beta_{0.75R} = 60^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	3.689		3.540		3.405		3.265	
0.20	0.019	<b>0.052</b>	0.014	0.050	0.005	0.049	0.012	<b>0.047</b>
.35	.176	.124	.169	.125	.182	.125	.185	.121
.48	.246	.162	.255	.168	.262	.169	.273	.164
.60	.314	.183	.331	.195	.333	.200	.362	.196
.71	.326	.187	.335	.206	.356	.216	.380	.215
.81	.303	.172	.327	.193	.347	.211	.380	.217
.89	.257	.146	.315	.171	.332	.191	.365	.192
.95	.183	.112	.215	.134	.251	.159	.255	.161
1.00	-.032	0	-.039	-.002	-.055	.007	-.042	.007
1.05	0	.009	0	.009	0	.010	0	.011
$\frac{V/nD}{x}$	2.984		2.696		2.551		2.402	
0.20	0.017	<b>0.043</b>	0.013	0.038	0.021	0.036	0.018	<b>0.034</b>
.35	.181	.107	.168	.092	.170	.086	.163	.081
.48	.262	.147	.249	.132	.262	.127	.261	.123
.60	.352	.182	.346	.170	.365	.168	.367	.172
.71	.392	.208	.381	.202	.425	.203	.425	.208
.81	.408	.215	.421	.215	.472	.218	.433	.218
.89	.417	.197	.412	.203	.441	.204	.383	.200
.95	.352	.171	.347	.167	.384	.177	.340	.169
1.00	0	.019	-.034	.016	-.015	.026	-.023	.026
1.05	0	.011	0	.010	0	.012	0	.008
$\frac{V/nD}{x}$	2.261		2.118		1.872		1.422	
0.20	0.022	0.032	<b>0.036</b>	0.031	0.052	0.028	0.062	<b>0.024</b>
.35	.166	.077	.173	.074	.177	.069	.156	.059
.48	.268	.118	.286	.116	.333	.124	.412	.133
.60	.390	.171	.425	.175	.429	.174	.304	.157
.71	.408	.202	.368	.190	.276	.158	.236	.145
.81	.348	.196	.325	.180	.276	.159	.351	.163
.89	.279	.174	.248	.160	.172	.142	.206	.140
.95	.229	.139	.161	.127	.086	.129	.098	.127
1.00	-.040	.026	-.032	.038	-.003	.084	.044	.109
1.05	.013	.005	0	.008	.014	.010	.007	.042
$\frac{V/nD}{x}$	1.139		0.868					
0.20	0.059	0.022	<b>0.046</b>	0.021				
.35	.171	.058	.176	.057				
.48	.426	.135	.386	.135				
.60	.282	.158	.272	.161				
.71	.208	.143	.154	.140				
.81	.276	.174	.312	.181				
.89	.237	.144	.243	.164				
.95	.097	.126	.106	.123				
1.00	.068	.116	.059	.109				
1.05	.007	.069	.028	.083				

TABLE 10.— WAKE SURVEY DATA; MODEL 3

$$[\beta_{0.75R} = 12^\circ]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	0.597		0.560		0.520	
0.20	0.011	0.001	0.014	0.001	0.017	0.002
.35	.030	.004	.038	.004	.050	.005
.48	.052	.006	.065	.007	.079	.008
.60	.056	.007	.071	.008	.085	.009
.71	.037	.005	.054	.007	.072	.008
.81	.014	.004	.033	.005	.051	.007
.89	-.010	.002	.009	.003	.020	.004
.95	-.028	.003	-.015	.004	-.001	.005
1.00	-.011	.007	-.007	.005	-.002	.002
1.05	0	0	0	0	0	0
$\frac{V/nD}{x}$	0.482		0.401		0.319	
0.20	0.019	0.002	0.023	0.002	0.025	0.002
.35	.058	.006	.067	.006	.069	.006
.48	.090	.009	.108	.010	.114	.010
.60	.100	.010	.128	.012	.148	.013
.71	.087	.009	.120	.011	.146	.013
.81	.068	.008	.102	.010	.132	.011
.89	.042	.006	.070	.008	.103	.009
.95	.009	.005	.009	.006	0	.002
1.00	-.001	.002	0	.001	.001	0
1.05	.001	.001	.001	0	.001	0

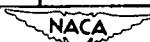


TABLE 10.- WAKE SURVEY DATA; MODEL 3 - Continued

$$\left[ \beta_{0.75R} = 19^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V}{nD}$ x	0.904		0.855		0.804		0.702	
0.20	-0.012	-0.001	0.001	0	0.009	0.001	0.017	0.002
.35	.010	.002	.023	.004	.034	.005	.056	.008
.48	.036	.006	.053	.008	.069	.010	.102	.014
.60	.050	.008	.070	.011	.090	.014	.131	.017
.71	.044	.008	.067	.011	.091	.014	.139	.019
.81	.035	.007	.060	.010	.087	.013	.137	.018
.89	.018	.004	.043	.008	.068	.011	.115	.015
.95	-.001	.005	.017	.008	.038	.009	.076	.012
1.00	-.011	.001	-.008	.002	-.003	.001	-.001	.001
1.05	-.003	0	-.002	0	0	.001	0	.001
$\frac{V}{nD}$ x	0.603		0.500		0.402		0.303	
0.20	0.024	0.003	0.027	0.003	0.028	0.002	0.030	0.002
.35	.071	.009	.074	.008	.079	.008	.083	.008
.48	.120	.015	.123	.014	.130	.013	.137	.014
.60	.164	.020	.171	.019	.179	.019	.185	.020
.71	.186	.023	.209	.024	.214	.023	.227	.024
.81	.184	.022	.223	.025	.236	.025	.250	.026
.89	.160	.019	.200	.022	.231	.024	.246	.024
.95	.105	.016	.039	.017	-.035	.012	-.056	.004
1.00	-.001	.002	-.001	.002	-.001	.002	-.007	.001
1.05	0	.001	0	.001	0	.001	-.001	0

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TABLE 10.— WAKE SURVEY DATA; MODEL 3 — Continued

$$\left[ \beta_{0.75R} = 27^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.267		1.213		1.149		1.085	
0.20	-0.023	-0.003	-0.016	-0.002	-0.008	0	0.004	0.001
.35	-.006	0	.009	.002	.023	0.005	.035	.007
.48	.028	.006	.046	.009	.063	.013	.082	.016
.60	.052	.011	.076	.015	.098	.019	.122	.023
.71	.061	.013	.088	.018	.110	.022	.138	.028
.81	.064	.013	.092	.019	.121	.024	.154	.029
.89	.056	.012	.083	.017	.112	.022	.142	.026
.95	.037	.011	.059	.014	.080	.017	.104	.022
1.00	-.003	.001	-.003	.001	-.006	.002	-.005	.003
1.05	0	0	0	0	0	.002	0	.002
$\frac{V/nD}{x}$	0.969		0.844		0.726		0.601	
0.20	0.015	0.003	0.024	0.004	0.028	0.004	0.029	0.003
.35	.060	.011	.077	.012	.080	.011	.088	.011
.48	.119	.021	.129	.020	.138	.020	.150	.019
.60	.170	.029	.181	.028	.192	.028	.213	.031
.71	.198	.035	.217	.035	.237	.036	.261	.039
.81	.213	.037	.245	.038	.265	.040	.296	.043
.89	.197	.034	.243	.038	.265	.039	.295	.041
.95	.154	.029	.206	.034	.235	.037	.251	.040
1.00	-.003	.004	0	.005	-.006	.006	-.005	.006
1.05	-.002	0	0	.002	-.002	.002	0	.002
$\frac{V/nD}{x}$	0.485		0.363					
0.20	0.031	0.003	0.034	0.003				
.35	.096	.011	.101	.011				
.48	.179	.024	.207	.027				
.60	.228	.034	.225	.035				
.71	.250	.043	.245	.044				
.81	.286	.047	.280	.053				
.89	.294	.043	.277	.048				
.95	.240	.040	-.040	.042				
1.00	-.008	.006	-.011	.006				
1.05	.001	.002	0	.002				

TABLE 10.— WAKE SURVEY DATA; MODEL 3 — Continued

$$\left[ \beta_{0.75R} = 37^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.803		1.726		1.653		1.512	
0.20	-0.024	-0.003	-0.017	-0.001	-0.009	0.001	0.004	0.004
.35	-.002	.001	.011	.005	.027	.009	.054	.015
.48	.036	.010	.053	.015	.073	.021	.114	.030
.60	.070	.020	.094	.026	.120	.033	.182	.044
.71	.089	.024	.116	.032	.148	.041	.207	.056
.81	.112	.028	.136	.038	.172	.046	.237	.062
.89	.111	.029	.137	.036	.172	.045	.233	.060
.95	.085	.027	.104	.033	.137	.039	.193	.053
1.00	0	0	.014	.001	-.011	.003	-.014	.007
1.05	0	0	.001	0	0	.001	-.009	.002
$\frac{V/nD}{x}$	1.367		1.224		1.002		0.856	
0.20	0.019	0.006	0.028	0.007	0.031	0.006	0.032	0.005
.35	.079	.019	.089	.020	.094	.017	.101	.017
.48	.142	.034	.147	.032	.166	.031	.193	.035
.60	.200	.047	.208	.046	.252	.050	.301	.059
.71	.232	.057	.252	.058	.306	.067	.280	.065
.81	.268	.064	.298	.067	.336	.077	.289	.074
.89	.277	.065	.304	.067	.334	.074	.293	.077
.95	.252	.061	.282	.064	.319	.066	.271	.068
1.00	0	.009	-.006	.009	-.013	.010	-.003	.023
1.05	0	.005	-.002	.004	-.003	.003	-.002	.005
$\frac{V/nD}{x}$	0.643		0.510					
0.20	0.037	0.005	0.040	0.005				
.35	.117	.017	.127	.019				
.48	.250	.043	.278	.048				
.60	.276	.057	.240	.050				
.71	.263	.060	.273	.061				
.81	.312	.079	.329	.082				
.89	.320	.087	.290	.105				
.95	.183	.103	.144	.089				
1.00	.007	.037	.017	.041				
1.05	0	.008	-.009	.010				

TABLE 10.— WAKE SURVEY DATA; MODEL 3 — Continued

$$\left[ \beta_{0.75R} = 48^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	2.580		2.487		2.385		2.279	
0.20	-0.003	0.009	0.004	0.011	0.006	0.012	0.016	0.014
.35	.037	.020	.051	.026	.058	.029	.079	.033
.48	.065	.032	.084	.039	.094	.045	.131	.052
.60	.104	.045	.128	.054	.150	.062	.198	.073
.71	.122	.050	.155	.063	.174	.076	.232	.089
.81	.148	.056	.181	.070	.203	.085	.274	.100
.89	.158	.058	.186	.071	.207	.086	.280	.100
.95	.119	.054	.148	.066	.166	.078	.240	.089
1.00	0	0	-.029	0	-.031	.007	0	.010
1.05	0	0	-.010	0	-.014	.004	0	.005
$\frac{V/nD}{x}$	2.182		1.985		1.788		1.592	
0.20	0.022	0.019	0.030	0.016	0.033	0.016	0.033	0.013
.35	.093	.037	.108	.040	.108	.036	.109	.031
.48	.158	.059	.166	.059	.167	.055	.183	.052
.60	.229	.082	.232	.080	.240	.077	.271	.079
.71	.258	.098	.264	.096	.287	.098	.342	.106
.81	.288	.106	.311	.109	.344	.116	.374	.128
.89	.299	.107	.328	.110	.353	.118	.368	.124
.95	.263	.100	.309	.106	.336	.111	.350	.112
1.00	-.019	.013	-.016	.014	-.030	.015	-.018	.021
1.05	-.004	.004	0	.005	-.013	.006	0	.007
$\frac{V/nD}{x}$	1.383		1.087		0.893		0.697	
0.20	0.034	0.011	0.041	0.009	0.044	0.009	0.047	0.009
.35	.113	.029	.127	.028	.136	.029	.151	.031
.48	.203	.054	.275	.064	.313	.071	.307	.075
.60	.337	.092	.278	.083	.242	.083	.245	.088
.71	.304	.101	.278	.089	.306	.100	.333	.111
.81	.308	.108	.334	.104	.371	.110	.365	.113
.89	.290	.111	.285	.109	.253	.102	.223	.107
.95	.247	.106	.167	.115	.130	.109	.106	.103
1.00	.006	.055	.034	.084	.058	.096	.064	.101
1.05	0	.008	-.016	.039	.002	.069	.024	.085

TABLE 10.— WAKE SURVEY DATA; MODEL 3 — Concluded

$$\left[ \beta_{0.75R} = 60^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	3.686		3.551		3.403		3.120	
0.20	0.043	0.054	0.038	0.052	0.038	0.050	0.029	0.044
.35	.172	.117	.170	.116	.172	.112	.142	.094
.48	.220	.138	.228	.143	.244	.141	.206	.125
.60	.263	.155	.303	.166	.322	.169	.289	.159
.71	.265	.160	.309	.176	.336	.189	.299	.180
.81	.277	.162	.329	.185	.369	.196	.341	.197
.89	.266	.171	.317	.193	.364	.206	.361	.211
.95	.203	.145	.263	.163	.311	.175	.334	.189
1.00	-.053	.026	-.030	.026	-.018	.035	-.046	.034
1.05	0	.010	0	.007	0	.008	-.032	.007
$\frac{V/nD}{x}$	2.843		2.695		2.548		2.404	
0.20	0.034	0.038	0.027	0.034	0.033	0.031	0.032	0.028
.35	.147	.080	.132	.073	.136	.068	.133	.064
.48	.222	.114	.205	.107	.208	.101	.211	.097
.60	.305	.149	.298	.145	.306	.141	.316	.141
.71	.334	.179	.352	.180	.362	.181	.358	.179
.81	.381	.203	.402	.208	.409	.210	.364	.197
.89	.401	.215	.432	.220	.427	.219	.408	.207
.95	.380	.200	.423	.202	.426	.197	.392	.187
1.00	-.032	.033	-.029	.036	-.036	.037	-.027	.050
1.05	-.007	.011	0	.014	0	.013	0	.009
$\frac{V/nD}{x}$	2.262		1.980		1.688		1.410	
0.20	0.031	0.026	0.041	0.022	0.047	0.019	0.049	0.017
.35	.135	.058	.140	.055	.154	.056	.163	.055
.48	.224	.095	.270	.104	.230	.081	.175	.088
.60	.328	.143	.235	.116	.191	.100	.208	.111
.71	.317	.165	.265	.140	.297	.139	.350	.144
.81	.329	.177	.334	.165	.344	.158	.334	.145
.89	.308	.185	.255	.162	.223	.149	.217	.137
.95	.332	.170	.190	.154	.134	.152	.153	.155
1.00	-.020	.072	-.003	.102	.034	.128	.100	.146
1.05	0	.008	-.006	.015	-.021	.050	.013	.089
$\frac{V/nD}{x}$	1.138		0.862					
0.20	0.053	0.017	0.049	0.016				
.35	.166	.053	.179	.052				
.48	.182	.085	.161	.083				
.60	.221	.112	.169	.107				
.71	.347	.152	.341	.158				
.81	.310	.138	.280	.144				
.89	.211	.136	.192	.137				
.95	.173	.155	.174	.155				
1.00	.186	.170	.197	.175				
1.05	.027	.125	.077	.149				

TABLE 11.- WAKE SURVEY DATA; MODEL 4

$$\left[ \beta_{0.75R} = 12^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	0.600		0.565		0.522	
0.20	0.011	0.001	0.014	0.002	0.017	0.002
.35	.040	.005	.052	.006	.062	.006
.48	.066	.007	.082	.009	.098	.009
.60	.073	.009	.090	.010	.107	.012
.71	.050	.007	.071	.009	.089	.010
.81	.001	.003	.020	.004	.039	.006
.89	-.042	0	-.026	.002	-.010	.003
.95	-.054	0	-.045	0	-.033	.001
1.00	0	.005	0	.005	-.001	.003
1.05	.001	0	.001	0	0	.001
$\frac{V/nD}{x}$	0.482		0.402		0.321	
0.20	0.020	0.002	0.024	0.002	0.027	0.002
.35	.070	.007	.084	.008	.090	.009
.48	.109	.012	.133	.014	.146	.014
.60	.123	.013	.154	.016	.176	.017
.71	.107	.012	.140	.014	.167	.016
.81	.056	.007	.088	.009	.113	.011
.89	.002	.004	.019	.006	.018	.005
.95	-.022	.001	-.005	0	.001	0
1.00	0	.001	0	0	0	0
1.05	0	.001	0	0	0	0



TABLE 11.— WAKE SURVEY DATA; MODEL 4 — Continued

$$\left[ \beta_{0.75R} = 19^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	0.901		0.853		0.804		0.704	
0.20	-0.002	0	0.005	0.001	0.010	0.002	0.015	0.002
.35	.024	0.004	.036	.006	.051	.008	.073	.010
.48	.056	.009	.075	.012	.096	.014	.129	.018
.60	.076	.013	.099	.016	.122	.018	.162	.022
.71	.064	.012	.092	.015	.118	.018	.166	.023
.81	.030	.007	.058	.011	.084	.014	.133	.018
.89	-.011	.003	.013	.006	.036	.009	.077	.012
.95	-.034	.004	-.016	.003	0	.004	.023	.005
1.00	-.006	.004	-.003	.002	0	.001	.002	.001
1.05	-.002	0	-.001	.001	0	.001	0	.001
$\frac{V/nD}{x}$	0.604		0.503		0.404		0.304	
0.20	0.022	0.003	0.022	0.003	0.031	0.003	0.035	0.003
.35	.090	.011	.097	.011	.010	.011	.107	.011
.48	.151	.019	.158	.019	.167	.019	.175	.019
.60	.196	.025	.214	.025	.221	.026	.232	.026
.71	.208	.027	.240	.028	.252	.029	.262	.030
.81	.177	.022	.221	.025	.252	.027	.251	.026
.89	.114	.015	.160	.018	.179	.021	.079	.016
.95	.009	.005	-.001	.003	-.006	.003	-.003	.001
1.00	0	.001	.008	.001	-.001	.001	-.001	.001
1.05	0	.001	0	.001	0	.001	0	0

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TABLE 11.— WAKE SURVEY DATA; MODEL 4 — Continued

$$\left[ \beta_{0.75R} = 27^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.272		1.206		1.153		1.092	
0.20	-0.014	-0.002	-0.006	0	0.004	0.001	0.009	0.002
.35	.013	.003	.024	0.006	.038	.008	.054	.011
.48	.049	.011	.069	.014	.090	.018	.114	.022
.60	.079	.017	.106	.022	.132	.026	.157	.030
.71	.082	.018	.110	.024	.137	.028	.167	.034
.81	.059	.014	.090	.020	.118	.025	.148	.030
.89	.025	.009	.052	.014	.076	.018	.101	.022
.95	0	.004	.015	.007	.031	.009	.047	.012
1.00	0	.001	-.005	.001	-.004	.002	-.007	.002
1.05	0	0	0	0	0	.001	0	.001
$\frac{V/nD}{x}$	1.020		0.909		0.787		0.605	
0.20	0.010	0.003	0.017	0.004	0.025	0.004	0.032	0.004
.35	.069	.013	.093	.014	.103	.016	.114	.015
.48	.133	.025	.162	.028	.171	.027	.193	.027
.60	.182	.034	.219	.038	.231	.036	.266	.039
.71	.199	.038	.246	.043	.269	.043	.306	.046
.81	.186	.034	.241	.041	.272	.042	.306	.043
.89	.134	.026	.193	.032	.230	.035	.263	.036
.95	.067	.015	.093	.020	.091	.022	.006	.011
1.00	0	.002	0	.003	.002	.003	0	.003
1.05	0	.001	0	.001	0	.002	0	.002
$\frac{V/nD}{x}$	0.483		0.363					
0.20	0.038	0.004	0.041	0.004				
.35	.124	.016	.128	.016				
.48	.212	.029	.232	.033				
.60	.301	.045	.329	.050				
.71	.326	.053	.318	.062				
.81	.308	.047	.275	.052				
.89	.272	.039	.116	.053				
.95	-.019	.008	-.012	.008				
1.00	0	.002	-.003	.002				
1.05	0	.001	0	.001				

TABLE 11.— WAKE SURVEY DATA; MODEL 4 — Continued

$$\left[ \beta_{0.75R} = 37^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.807		1.726		1.657		1.584	
0.20	-0.014	0	-0.007	0.001	-0.002	0.002	0.009	0.004
.35	.015	0.008	.032	.010	.045	.013	.067	.017
.48	.058	.019	.082	.024	.105	.029	.130	.035
.60	.097	.030	.132	.036	.159	.043	.188	.050
.71	.109	.034	.148	.042	.178	.050	.211	.054
.81	.098	.029	.136	.039	.168	.046	.207	.055
.89	.066	.025	.104	.031	.131	.039	.165	.047
.95	.027	.012	.051	.018	.072	.023	.096	.029
1.00	-.007	0	-.009	.002	-.008	.003	-.008	.004
1.05	0	0	0	0	0	.002	0	.002
$\frac{V/nD}{x}$	1.516		1.369		1.154		0.939	
0.20	0.016	0.006	0.018	0.007	0.023	0.008	0.034	0.007
.35	.078	.023	.106	.025	.115	.026	.127	.024
.48	.147	.039	.193	.045	.193	.042	.223	.043
.60	.211	.055	.258	.060	.268	.059	.328	.066
.71	.236	.064	.281	.069	.313	.071	.382	.085
.81	.240	.063	.291	.069	.326	.072	.358	.082
.89	.199	.054	.248	.060	.284	.063	.299	.073
.95	.129	.036	.178	.044	.201	.049	.062	.046
1.00	-.007	.004	-.010	.005	0	.006	-.002	.006
1.05	0	.003	0	.004	-.002	.004	-.004	.004
$\frac{V/nD}{x}$	0.719		0.507					
0.20	0.041	0.007	0.048	0.007				
.35	.141	.024	.151	.025				
.48	.262	.048	.310	.056				
.60	.406	.078	.469	.093				
.71	.417	.099	.308	.083				
.81	.267	.076	.222	.077				
.89	.155	.067	.148	.089				
.95	.054	.050	.044	.055				
1.00	-.003	.014	0	.025				
1.05	0	.004	-.002	.009				

TABLE 11.— WAKE SURVEY DATA; MODEL 4 — Continued

$$\left[ \beta_{0.75R} = 48^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	2.600		2.507		2.400		2.305	
0.20	0.008	0.011	0.007	0.012	0.006	0.014	0.014	0.015
.35	.052	.027	.059	.032	.073	.036	.094	.042
.48	.097	.045	.116	.052	.135	.061	.168	.069
.60	.137	.058	.169	.072	.195	.079	.238	.088
.71	.147	.064	.179	.077	.209	.090	.258	.102
.81	.125	.056	.168	.069	.198	.084	.257	.100
.89	.085	.050	.132	.062	.165	.075	.219	.088
.95	.040	.027	.075	.037	.090	.048	.143	.056
1.00	-.021	0	-.025	.002	-.032	.009	-.021	.008
1.05	0	0	-.010	0	-.019	0	-.004	0
$\frac{V/nD}{x}$	2.202		2.006		1.801		1.599	
0.20	0.018	0.015	0.015	0.016	0.020	0.015	0.025	0.014
.35	.109	.044	.122	.049	.139	.048	.140	.043
.48	.192	.074	.206	.079	.216	.071	.230	.069
.60	.267	.097	.283	.101	.300	.097	.333	.099
.71	.292	.112	.303	.115	.340	.116	.394	.126
.81	.296	.110	.323	.115	.357	.120	.411	.129
.89	.254	.099	.281	.104	.306	.108	.334	.120
.95	.181	.070	.213	.076	.232	.083	.185	.084
1.00	-.023	.008	-.016	-.003	-.028	.010	0	.011
1.05	0	.004	0	.006	-.019	.006	0	.006
$\frac{V/nD}{x}$	1.501		1.296		0.997		0.699	
0.20	0.029	0.013	0.036	0.012	0.050	0.011	0.055	0.012
.35	.140	.041	.150	.040	.163	.037	.162	.036
.48	.239	.068	.267	.070	.321	.078	.366	.088
.60	.353	.103	.439	.116	.547	.137	.523	.158
.71	.419	.133	.432	.140	.334	.115	.222	.095
.81	.389	.131	.288	.112	.260	.099	.241	.105
.89	.282	.112	.194	.095	.150	.094	.145	.110
.95	.136	.074	.074	.071	.065	.085	.064	.094
1.00	-.005	.010	0	.021	.027	.070	.029	.078
1.05	0	.006	0	.006	-.007	.026	-.003	.049

TABLE 11.— WAKE SURVEY DATA; MODEL 4 — Concluded

$$\left[ \beta_{0.75R} = 60^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	3.713		3.552		3.402		3.130	
0.20	0.011	0.054	0.026	0.053	0.009	0.050	0.018	0.046
.35	.163	.131	.198	.132	.185	.130	.197	.123
.48	.244	.174	.285	.179	.288	.180	.284	.169
.60	.312	.194	.363	.206	.382	.210	.374	.204
.71	.292	.193	.366	.209	.400	.220	.382	.219
.81	.263	.164	.337	.190	.390	.207	.386	.215
.89	.193	.152	.21	.169	.324	.185	.342	.196
.95	.103	.094	.179	.115	.233	.130	.249	.142
1.00	-.054	.011	-.030	.008	0	.021	-.023	.019
1.05	-.045	.010	0	0	0	0	0	.008
$\frac{V/nD}{x}$	2.835		2.693		2.577		2.442	
0.20	0.008	0.041	0.015	0.038	0.014	0.037	0.016	0.033
.35	.170	.107	.179	.095	.167	.091	.166	.082
.48	.261	.145	.268	.139	.264	.136	.259	.129
.60	.368	.186	.379	.182	.366	.180	.374	.178
.71	.390	.215	.412	.211	.416	.211	.435	.215
.81	.399	.215	.438	.217	.440	.219	.451	.220
.89	.360	.199	.385	.197	.367	.201	.350	.197
.95	.270	.152	.281	.148	.263	.141	.240	.136
1.00	-.019	.022	-.023	.020	-.031	.021	0	.019
1.05	0	.013	0	.011	-.011	.010	0	.009
$\frac{V/nD}{x}$	2.291		1.976		1.699		1.419	
0.20	0.021	0.031	0.041	0.028	0.051	0.025	0.061	0.023
.35	.168	.078	.173	.072	.164	.067	.164	.062
.48	.269	.124	.300	.122	.363	.131	.399	.135
.60	.403	.181	.482	.193	.496	.198	.456	.197
.71	.434	.220	.349	.190	.276	.156	.226	.142
.81	.357	.210	.246	.168	.224	.151	.283	.159
.89	.253	.175	.141	.144	.160	.139	.151	.138
.95	.172	.113	.061	.106	.043	.119	.063	.123
1.00	0	.016	-.021	.038	-.007	.084	.024	.100
1.05	0	.008	-.006	.008	0	.017	-.005	.034
$\frac{V/nD}{x}$	1.136		0.869					
0.20	0.053	0.024	0.038	0.022				
.35	.170	.062	.196	.065				
.48	.384	.128	.407	.137				
.60	.376	.170	.283	.163				
.71	.202	.140	.118	.138				
.81	.274	.154	.238	.171				
.89	.160	.151	.182	.164				
.95	.061	.128	.080	.129				
1.00	.065	.124	.053	.118				
1.05	0	.086	.008	.091				

TABLE 12.—WAKE SURVEY DATA; MODEL 5

$$\left[ \beta_{0.75R} = 12^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	0.602		0.563		0.520	
0.20	0.009	0.001	0.014	0.001	0.016	0.001
.35	.032	.004	.041	.005	.051	.006
.48	.062	.007	.077	.009	.090	.010
.60	.067	.008	.084	.009	.100	.011
.71	.043	.006	.063	.008	.082	.010
.81	.001	.003	.021	.005	.040	.006
.89	-.038	0	-.021	.001	-.005	.003
.95	-.051	-.001	-.040	-.001	-.026	0
1.00	-.001	.004	-.001	.004	0	.002
1.05	.001	0	.001	0	0	.001
$\frac{V/nD}{x}$	0.483		0.402		0.322	
0.20	0.019	0.002	0.022	0.002	0.024	0.002
.35	.061	.006	.074	.007	.077	.007
.48	.103	.011	.124	.012	.137	.013
.60	.117	.012	.144	.015	.172	.016
.71	.100	.011	.132	.013	.164	.016
.81	.058	.007	.090	.009	.117	.011
.89	.008	.004	.025	.006	.033	.006
.95	-.016	.001	-.001	.001	0	0
1.00	0	0	0	0	.001	0
1.05	0	0	.001	0	.001	0

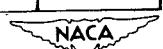


TABLE 12.— WAKE SURVEY DATA; MODEL 5 — Continued

$$\left[ \beta_{0.75R} = 19^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	0.897		0.850		0.804		0.705	
0.20	-0.010	-0.001	0.004	0.001	0.008	0.001	0.015	0.002
.35	.013	.002	.029	.004	.041	.006	.063	.008
.48	.047	.008	.066	.010	.087	.013	.119	.016
.60	.067	.011	.089	.014	.114	.017	.154	.021
.71	.059	.010	.082	.013	.108	.017	.157	.022
.81	.030	.007	.056	.010	.082	.013	.132	.017
.89	-.007	.002	.015	.004	.039	.007	.079	.011
.95	-.026	0	-.012	.002	.002	.003	.026	.005
1.00	-.004	.002	-.002	0	0	0	-.002	0
1.05	-.001	0	0	0	.001	0	.001	.001
$\frac{V/nD}{x}$	0.600		0.502		0.398		0.300	
0.20	0.021	0.003	0.025	0.003	0.027	0.002	0.030	0.002
.35	.080	.010	.084	.009	.088	.009	.094	.009
.48	.141	.018	.145	.017	.152	.017	.164	.017
.60	.191	.024	.196	.025	.207	.024	.222	.025
.71	.205	.026	.224	.028	.240	.027	.258	.029
.81	.180	.022	.220	.025	.240	.025	.252	.026
.89	.122	.015	.163	.018	.189	.020	.109	.017
.95	.012	.006	-.001	.004	-.006	.003	.009	.001
1.00	0	.001	-.001	.001	0	.001	0	.001
1.05	0	.001	.003	.001	0	.001	.002	.001



TABLE 12.— WAKE SURVEY DATA; MODEL 5 — Continued

$$\left[ \beta_{0.75R} = 27^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.285		1.223		1.160		1.098	
0.20	-0.028	-0.003	-0.022	-0.003	-0.014	-0.001	-0.007	---
.35	-.005	0	.006	.002	.024	.006	.038	.008
.48	.029	.007	.050	.011	.074	.015	.095	.019
.60	.057	.013	.083	.018	.112	.023	.140	.027
.71	.063	.014	.088	.020	.120	.026	.152	.030
.81	.046	.012	.074	.017	.102	.023	.141	.028
.89	.019	.005	.040	.010	.072	.015	.099	.019
.95	-.006	.003	.007	.005	.029	.010	.049	.012
1.00	-.003	.001	-.011	-.001	-.007	0	-.009	.002
1.05	0	0	-.009	0	-.002	.001	-.002	.002
$\frac{V/nD}{x}$	1.039		0.914		0.793		0.610	
0.20	0.003	0.001	0.017	0.003	0.025	0.004	0.029	0.003
.35	.050	.010	.076	.013	.089	.014	.100	.013
.48	.115	.022	.150	.025	.156	.024	.179	.025
.60	.167	.031	.210	.035	.217	.034	.253	.036
.71	.181	.036	.244	.043	.260	.041	.298	.045
.81	.174	.033	.239	.039	.264	.041	.307	.044
.89	.128	.024	.189	.031	.224	.034	.266	.037
.95	.067	.015	.103	.022	.115	.024	-.008	.020
1.00	-.008	.001	-.004	.002	-.001	.002	-.001	.003
1.05	-.004	.002	-.001	.002	-.001	.002	0	.002
$\frac{V/nD}{x}$	0.486		0.372					
0.20	0.031	0.003	0.034	0.003				
.35	.105	.013	.114	.013				
.48	.196	.027	.220	.031				
.60	.273	.041	.297	.046				
.71	.320	.051	.325	.057				
.81	.317	.048	.305	.055				
.89	.280	.039	.148	.041				
.95	-.022	.009	-.022	.009				
1.00	.001	.003	-.003	.002				
1.05	.001	.002	0	.001				

TABLE 12.— WAKE SURVEY DATA; MODEL 5 — Continued

$$\left[ \beta_{0.75R} = 37^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.798		1.734		1.661		1.591	
0.20	-0.026	-0.003	-0.021	-0.002	-0.014	-0.001	-0.010	0.001
.35	.001	.002	.014	.005	.030	.009	.041	.013
.48	.043	.014	.065	.019	.090	.025	.112	.031
.60	.082	.026	.115	.031	.143	.039	.169	.046
.71	.103	.031	.136	.037	.165	.046	.193	.056
.81	.097	.028	.130	.035	.165	.044	.198	.055
.89	.066	.021	.099	.026	.133	.034	.161	.044
.95	.031	.013	.052	.018	.078	.023	.098	.031
1.00	-.010	-.004	-.014	-.001	-.011	0	-.014	0
1.05	0	0	0	0	0	.001	-.008	.002
$\frac{V/nD}{x}$	1.515		1.371		1.222		0.940	
0.20	0.002	0.002	0.016	0.005	0.025	0.006	0.030	0.006
.35	.061	.016	.078	.020	.098	.022	.111	.020
.48	.138	.035	.158	.038	.172	.038	.207	.039
.60	.206	.052	.212	.053	.244	.054	.309	.062
.71	.242	.063	.254	.064	.289	.067	.368	.081
.81	.245	.062	.264	.065	.311	.070	.387	.084
.89	.189	.051	.229	.054	.272	.060	.302	.073
.95	.139	.036	.170	.042	.204	.048	.069	.050
1.00	-.007	.001	-.008	.003	-.005	.004	0	.005
1.05	0	.002	-.004	.004	-.004	.003	0	.004
$\frac{V/nD}{x}$	0.720		0.510					
0.20	0.035	0.005	0.042	0.005				
.35	.124	.020	.136	.022				
.48	.246	.045	.300	.054				
.60	.386	.076	.416	.084				
.71	.370	.086	.351	.084				
.81	.333	.085	.273	.088				
.89	.194	.078	.138	.089				
.95	.048	.048	.052	.057				
1.00	0	.013	.003	.026				
1.05	0	.004	0	.009				

TABLE 12.- WAKE SURVEY DATA; MODEL 5 - Continued

$$\left[ \beta_{0.75R} = 48^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	2.631		2.538		2.392		2.314	
0.20	-0.010	0.004	-0.005	0.006	0.007	0.009	0.009	0.010
.35	.029	.016	.048	.025	.069	.031	.075	.033
.48	.076	.034	.108	.046	.134	.055	.143	.059
.60	.114	.047	.155	.063	.197	.075	.212	.081
.71	.139	.050	.173	.071	.223	.087	.239	.094
.81	.132	.045	.172	.067	.237	.085	.252	.094
.89	.097	.034	.126	.052	.200	.067	.213	.078
.95	.057	.023	.067	.037	.137	.049	.144	.057
1.00	-.005	-.005	-.035	-.004	0	0	-.017	0
1.05	.011	-.001	-.021	-.001	.009	.004	0	0
$\frac{V/nD}{x}$	2.222		2.016		1.811		1.616	
0.20	0.015	0.012	0.027	0.014	0.028	0.014	0.029	0.013
.35	.085	.038	.114	.043	.124	.042	.120	.036
.48	.167	.066	.201	.072	.201	.066	.212	.063
.60	.244	.092	.276	.094	.284	.092	.313	.093
.71	.275	.113	.313	.111	.329	.114	.380	.122
.81	.283	.109	.318	.114	.371	.120	.417	.130
.89	.248	.093	.281	.099	.330	.108	.338	.117
.95	.177	.070	.218	.078	.254	.088	.185	.089
1.00	-.027	.004	-.013	.006	-.015	.008	-.021	.008
1.05	-.012	0	0	.005	-.008	.005	0	.005
$\frac{V/nD}{x}$	1.508		1.302		1.000		0.701	
0.20	0.029	0.012	0.036	0.010	0.041	0.009	0.061	0.010
.35	.119	.035	.132	.033	.142	.033	.162	.036
.48	.219	.063	.248	.065	.317	.076	.349	.083
.60	.333	.097	.407	.109	.501	.127	.434	.123
.71	.417	.130	.444	.140	.367	.116	.303	.102
.81	.399	.136	.301	.117	.272	.106	.261	.109
.89	.272	.111	.187	.095	.152	.097	.143	.114
.95	.136	.077	.067	.074	.062	.087	.049	.098
1.00	-.009	.009	-.012	.026	.024	.074	.028	.090
1.05	0	.004	0	.004	-.010	.031	.002	.077

TABLE 12.— WAKE SURVEY DATA; MODEL 5 — Concluded

$$\left[ \beta_{0.75R} = 60^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	
$\frac{V/nD}{x}$	3.678		3.534		3.410		3.266		
0.20	0.021	0.048	0.008	0.046	0.007	0.045	0.013	0.043	
.35	.167	.124	.158	.121	.160	.119	.173	.116	
.48	.240	.164	.240	.169	.246	.171	.261	.161	
.60	.306	.185	.312	.198	.340	.200	.347	.197	
.71	.294	.188	.306	.207	.357	.215	.351	.217	
.81	.284	.167	.294	.191	.326	.201	.346	.209	
.89	.208	.133	.236	.158	.285	.164	.291	.176	
.95	.121	.096	.149	.119	.191	.122	.191	.140	
1.00	-.053	.002	-.069	0	-.055	.002	-.067	.010	
1.05	0	.014	-.041	.004	-.029	.004	-.035	.013	
$\frac{V/nD}{x}$	2.982		2.699		2.548		2.263		
0.20	0.018	0.037	0.019	0.032	0.024	0.029	0.027	0.025	
.35	.174	.097	.156	.083	.150	.077	.144	.068	
.48	.258	.140	.250	.128	.247	.122	.245	.113	
.60	.352	.181	.350	.173	.358	.171	.393	.173	
.71	.382	.208	.394	.207	.402	.209	.440	.213	
.81	.396	.212	.431	.217	.434	.221	.365	.206	
.89	.348	.182	.372	.193	.372	.200	.251	.168	
.95	.246	.146	.283	.154	.252	.152	.134	.115	
1.00	-.056	.011	-.051	.012	-.046	.015	-.048	.016	
1.05	-.022	.009	-.018	.012	-.032	.010	-.034	.007	
$\frac{V/nD}{x}$	1.97		1.836		1.691		1.558		
0.20	0.035	0.021	0.040	0.020	0.042	0.019	0.037	0.018	
.35	.146	.061	.151	.059	.142	.060	.133	.055	
.48	.285	.116	.324	.120	.311	.119	.316	.116	
.60	.452	.182	.480	.185	.443	.179	.382	.157	
.71	.348	.183	.318	.168	.290	.157	.310	.157	
.81	.249	.165	.242	.158	.214	.153	.261	.154	
.89	.141	.139	.144	.133	.094	.131	.122	.131	
.95	.058	.114	.048	.118	.012	.125	.022	.127	
1.00	-.037	.038	-.021	.073	-.022	.104	-.004	.120	
1.05	-.029	.006	.006	.012	-.009	.020	-.028	.049	
$\frac{V/nD}{x}$	1.275		0.868						
0.20	0.031	0.020	0.036	0.019					
.35	.085	.050	.183	.061					
.48	.266	.102	.260	.105					
.60	.377	.147	.246	.139					
.71	.300	.152	.278	.160					
.81	.249	.147	.250	.168					
.89	.112	.139	.131	.151					
.95	.023	.139	.065	.129					
1.00	.062	.151	.092	.139					
1.05	0	.108	.040	.120					

TABLE 13.— WAKE SURVEY DATA; MODEL 6

$$\left[ \beta_{0.75R} = 12^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{x}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	0.605		0.563		0.525	
0.20	0.003	0	0.006	0.001	0.010	0.001
.35	.025	0	.031	.004	.039	.004
.48	.041	0.005	.052	.006	.064	.007
.60	.047	.006	.063	.007	.077	.008
.71	.026	.004	.046	.006	.064	.007
.81	-.007	.002	.013	.004	.031	.005
.89	-.040	.001	-.018	.002	-.002	.004
.95	-.054	0	-.037	.002	-.024	.003
1.00	-.006	.013	-.007	.010	-.006	.007
1.05	0	0	0	0	0	.001
$\frac{V/nD}{x}$	0.485		0.404		0.324	
0.20	0.013	0.001	0.026	0.002	0.024	0.002
.35	.048	.005	.079	.008	.063	.005
.48	.077	.008	.130	.012	.114	.010
.60	.092	.010	.156	.015	.148	.014
.71	.081	.009	.146	.014	.145	.013
.81	.050	.007	.106	.011	.112	.011
.89	.016	.005	.060	.008	.073	.008
.95	-.014	.005	-.003	.005	-.002	.001
1.00	-.003	.005	0	.001	0	0
1.05	0	.001	0	.001	0	0

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TABLE 13.— WAKE SURVEY DATA; MODEL 6 — Continued

$$\left[ \beta_{0.75R} = 19^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	0.874		0.850		0.804		0.702	
0.20	-0.014	-0.001	-0.007	0	-0.002	0	0.006	0.001
.35	.007	.002	.020	.004	.039	0.006	.051	.007
.48	.026	.005	.045	.007	.078	.012	.095	.013
.60	.043	.008	.067	.011	.113	.017	.132	.018
.71	.035	.007	.063	.011	.114	.018	.138	.019
.81	.017	.005	.046	.009	.095	.015	.127	.017
.89	-.006	.004	.020	.007	.060	.012	.095	.014
.95	-.021	.004	-.003	.006	.025	.009	.054	.010
1.00	-.011	.006	-.010	.003	-.005	.002	0	.001
1.05	-.003	0	-.002	0	0	.001	-.002	.001
$\frac{V/nD}{x}$	0.602		0.503		0.403		0.303	
0.20	0.017	0.002	0.024	0.002	0.027	0.002	0.029	0.002
.35	.067	.008	.068	.007	.073	.007	.078	.007
.48	.118	.014	.119	.013	.125	.013	.135	.014
.60	.168	.021	.173	.020	.183	.020	.195	.022
.71	.188	.024	.216	.025	.225	.025	.242	.026
.81	.175	.022	.220	.025	.245	.026	.259	.027
.89	.140	.018	.188	.021	.227	.024	.232	.026
.95	.061	.012	.005	.007	-.012	.004	-.032	.003
1.00	0	.002	.001	.001	-.002	.001	-.006	.001
1.05	-.001	.001	0	.001	0	.001	0	.001



TABLE 13.— WAKE SURVEY DATA; MODEL 6 — Continued

$$\left[ \beta_{0.75R} = 27^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.246		1.187		1.127		1.063	
0.20	-0.023	-0.003	-0.017	-0.001	-0.010	0	-0.006	0
.35	-.001	0	.012	.003	.023	0.005	.030	0.007
.48	.026	.006	.041	.009	.058	.012	.074	.014
.60	.056	.012	.078	.016	.102	.020	.123	.024
.71	.066	.014	.091	.019	.118	.024	.144	.029
.81	.060	.014	.089	.019	.112	.024	.148	.029
.89	.041	.013	.072	.017	.099	.022	.126	.026
.95	.022	.010	.041	.013	.067	.016	.086	.019
1.00	-.009	.001	-.006	.001	-.002	.002	-.006	.002
1.05	0	0	0	0	0	.001	-.003	.001
$\frac{V/nD}{x}$	1.002		0.879		0.755		0.637	
0.20	0.001	0.001	0.012	0.002	0.022	0.003	0.026	0.003
.35	.037	.008	.067	.011	.072	.010	.077	.010
.48	.098	.018	.124	.020	.129	.019	.138	.019
.60	.155	.028	.180	.029	.190	.029	.210	.031
.71	.180	.033	.223	.037	.239	.037	.261	.039
.81	.186	.033	.247	.040	.268	.040	.291	.041
.89	.159	.030	.224	.038	.263	.040	.285	.040
.95	.117	.022	.167	.030	.197	.036	.206	.036
1.00	0	.003	.001	.004	.001	.005	-.003	.005
1.05	0	.001	-.003	.002	0	.002	0	.002
$\frac{V/nD}{x}$	0.514		0.399					
0.20	0.028	0.003	0.030	0.003				
.35	.086	.010	.095	.011				
.48	.165	.022	.195	.026				
.60	.228	.034	.231	.036				
.71	.270	.043	.263	.048				
.81	.297	.045	.285	.050				
.89	.303	.041	.290	.045				
.95	.087	.033	-.094	.031				
1.00	-.007	.005	-.009	.004				
1.05	0	.002	0	.001				

TABLE 13.- WAKE SURVEY DATA; MODEL 6 - Continued

$$\left[ \beta_{0.75R} = 37^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.802		1.730		1.650		1.591	
0.20	-0.026	-0.003	-0.019	-0.002	-0.013	0	-0.011	0
.35	-.005	0	.007	.004	.022	0.008	.026	0.010
.48	.025	.008	.041	.013	.064	.018	.073	.022
.60	.066	.020	.086	.024	.119	.032	.131	.038
.71	.089	.025	.113	.032	.150	.042	.169	.049
.81	.097	.028	.124	.035	.163	.044	.188	.052
.89	.089	.027	.111	.033	.150	.043	.175	.050
.95	.061	.024	.078	.028	.114	.035	.132	.041
1.00	-.005	0	-.012	.002	-.011	.003	-.018	.005
1.05	0	0	0	0	0	.002	-.008	.002
$\frac{V/nD}{x}$	1.497		1.363		1.217		0.928	
0.20	-0.005	0.002	0.007	0.004	0.019	0.005	0.028	0.005
.35	.039	.012	.069	.017	.080	.018	.088	.016
.48	.095	.026	.134	.032	.138	.031	.169	.032
.60	.167	.044	.200	.048	.209	.047	.278	.055
.71	.205	.057	.239	.061	.261	.061	.304	.071
.81	.230	.061	.279	.068	.304	.069	.332	.076
.89	.218	.059	.280	.067	.301	.068	.329	.074
.95	.176	.049	.243	.060	.275	.063	.305	.063
1.00	-.007	.006	0	.007	-.005	.009	0	.012
1.05	0	.003	-.003	.004	-.004	.004	0	.004
$\frac{V/nD}{x}$	0.715		0.494					
0.20	0.033	0.005	0.037	0.005				
.35	.104	.016	.124	.019				
.48	.233	.041	.269	.047				
.60	.289	.058	.265	.054				
.71	.304	.070	.299	.069				
.81	.323	.080	.318	.082				
.89	.282	.080	.242	.109				
.95	.156	.084	.111	.091				
1.00	.006	.031	.007	.035				
1.05	0	.006	-.007	.009				

TABLE 13.— WAKE SURVEY DATA; MODEL 6 — Continued

$$\left[ \beta_{0.75R} = 48^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	2.588		2.490		2.386		2.295	
0.20	-0.011	0.006	-0.002	0.008	0.001	0.009	0.003	0.010
.35	.024	.017	.039	.021	.045	.023	.043	.027
.48	.053	.026	.075	.033	.092	.039	.101	.045
.60	.098	.041	.129	.050	.150	.060	.171	.069
.71	.120	.050	.156	.061	.184	.074	.217	.088
.81	.128	.053	.174	.067	.199	.080	.241	.095
.89	.112	.051	.165	.065	.195	.080	.239	.094
.95	.080	.045	.125	.056	.149	.068	.193	.081
1.00	-.026	.003	-.015	.004	-.022	.008	-.017	.008
1.05	0	.004	0	0	-.009	0	0	.004
$\frac{V/nD}{x}$	2.186		1.984		1.789		1.584	
0.20	0.011	0.011	0.023	0.014	0.029	0.014	0.030	0.013
.35	.074	.032	.101	.038	.098	.037	.092	.029
.48	.133	.053	.163	.059	.158	.053	.166	.050
.60	.216	.081	.236	.081	.241	.078	.272	.082
.71	.256	.101	.277	.101	.294	.102	.343	.112
.81	.289	.110	.331	.113	.346	.116	.383	.124
.89	.287	.108	.336	.114	.353	.118	.375	.125
.95	.239	.094	.305	.104	.330	.110	.352	.108
1.00	-.015	.010	0	.014	-.013	.016	-.006	.017
1.05	0	.005	0	.006	-.005	.008	0	.006
$\frac{V/nD}{x}$	1.483		1.291		0.992		0.697	
0.20	0.034	0.011	0.035	0.010	0.038	0.008	0.043	0.008
.35	.097	.027	.105	.026	.122	.028	.144	.031
.48	.170	.050	.217	.057	.289	.068	.269	.064
.60	.301	.086	.343	.093	.269	.079	.260	.085
.71	.344	.114	.319	.105	.298	.095	.354	.112
.81	.353	.120	.316	.112	.326	.109	.354	.115
.89	.340	.122	.292	.112	.270	.119	.195	.111
.95	.314	.102	.183	.108	.151	.119	.084	.101
1.00	0	.025	.009	.053	.023	.077	.054	.099
1.05	0	.007	0	.008	-.016	.033	.035	.080

TABLE 13.- WAKE SURVEY DATA; MODEL 6 - Concluded

$$\left[ \beta_{0.75R} = 60^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	3.577		3.428		3.279		3.009	
0.20	0.013	0.044	0.013	0.042	0.010	0.040	0.019	0.035
.35	.160	.107	.162	.103	.148	.096	.137	.081
.48	.210	.133	.230	.135	.231	.131	.212	.116
.60	.287	.164	.327	.173	.324	.171	.303	.157
.71	.303	.177	.354	.193	.354	.196	.343	.189
.81	.312	.177	.381	.197	.383	.206	.392	.205
.89	.287	.174	.378	.195	.376	.209	.392	.210
.95	.208	.129	.307	.151	.329	.166	.351	.171
1.00	-.060	0	0	.011	0	.015	-.021	.019
1.05	0	0	.029	0	.018	.006	0	.008
$\frac{V/nD}{x}$	2.721		2.575		2.425		2.289	
0.20	0.017	0.029	0.019	0.027	0.014	0.024	0.018	0.022
.35	.122	.067	.122	.062	.112	.058	.112	.055
.48	.201	.103	.203	.098	.186	.093	.196	.092
.60	.297	.146	.306	.146	.305	.146	.328	.149
.71	.355	.184	.377	.187	.374	.191	.348	.185
.81	.405	.205	.430	.210	.404	.209	.360	.193
.89	.404	.210	.436	.214	.419	.213	.363	.199
.95	.381	.183	.421	.185	.404	.181	.375	.170
1.00	-.052	.022	-.021	.025	-.023	.028	-.008	.041
1.05	-.018	.009	0	.009	0	.008	0	.010
$\frac{V/nD}{x}$	2.145		1.836		1.564		1.288	
0.20	0.022	0.024	0.029	0.017	0.036	0.016	0.047	0.017
.35	.116	.062	.136	.053	.135	.049	.100	.045
.48	.213	.113	.193	.083	.176	.080	.171	.078
.60	.327	.172	.261	.119	.252	.114	.335	.128
.71	.305	.199	.301	.152	.348	.150	.343	.145
.81	.319	.207	.300	.157	.279	.146	.278	.138
.89	.296	.212	.224	.157	.222	.152	.195	.145
.95	.254	.182	.113	.149	.115	.151	.129	.160
1.00	-.025	.065	0	.103	.048	.131	.136	.167
1.05	0	.014	0	.019	-.022	.054	0	.099
$\frac{V/nD}{x}$	0.858							
0.20	0.044	0.015						
.35	.154	.048						
.48	.127	.078						
.60	.231	.118						
.71	.350	.160						
.81	.239	.147						
.89	.171	.142						
.95	.153	.156						
1.00	.186	.174						
1.05	.048	.136						

TABLE 14.- WAKE SURVEY DATA; MODEL 7

$$\left[ \beta_{0.75R} = 12^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	0.600		0.560		0.519	
0.20	0.012	0.001	0.016	0.002	0.018	0.002
.35	.035	.004	.041	.004	.048	.005
.48	.053	.006	.062	.007	.073	.007
.60	.054	.006	.067	.007	.082	.008
.71	.029	.004	.048	.006	.069	.007
.81	-.034	-.001	-.016	.001	.003	.002
.89	-.063	-.002	-.046	0	-.028	.001
.95	-.070	-.002	-.056	-.001	-.041	0
1.00	-.005	.006	-.003	.001	-.002	.003
1.05	0	0	0	0	0	0
$\frac{V/nD}{x}$	0.489		0.401		0.325	
0.20	0.020	0.002	0.022	0.002	0.023	0.002
.35	.054	.005	.062	.006	.068	.006
.48	.085	.008	.098	.009	.111	.010
.60	.097	.010	.117	.011	.135	.012
.71	.086	.009	.112	.010	.134	.012
.81	.020	.003	.054	.005	.081	.007
.89	-.015	.002	.014	.004	.037	.005
.95	-.032	.001	-.008	.001	-.002	0
1.00	-.002	.002	0	0	-.002	0
1.05	-.002	0	0	0	0	0



TABLE 14.-- WAKE SURVEY DATA; MODEL 7 - Continued

$$\left[ \beta_{0.75R} = 19^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	0.860		0.807		0.711		0.658	
0.20	0.004	0.001	0.010	0.002	0.019	0.002	0.020	0.002
.35	.030	.005	.039	.006	.054	.007	.059	.008
.48	.052	.008	.066	.010	.092	.012	.102	.013
.60	.066	.010	.084	.012	.119	.015	.133	.017
.71	.055	.009	.081	.013	.124	.017	.143	.019
.81	.008	.003	.036	.006	.087	.011	.111	.014
.89	-.021	0	-.006	.003	.049	.007	.071	.010
.95	-.033	0	-.014	.002	.018	.004	.036	.006
1.00	-.005	.002	-.002	.002	0	0	.001	.001
1.05	-.003	0	0	0	.002	0	-.001	.001
$\frac{V/nD}{x}$	0.607		0.504		0.455		0.307	
0.20	0.021	0.002	0.024	0.002	0.025	0.002	0.030	0.002
.35	.065	.008	.075	.008	.078	.008	.085	.008
.48	.112	.014	.130	.014	.133	.014	.134	.014
.60	.148	.018	.174	.020	.182	.020	.195	.021
.71	.162	.020	.190	.022	.201	.023	.229	.025
.81	.137	.016	.177	.019	.184	.019	.217	.022
.89	.094	.012	.147	.016	.164	.017	.184	.020
.95	.048	.007	.011	.007	.004	.005	-.014	.002
1.00	0	.001	0	.001	-.001	.001	.002	.001
1.05	-.002	.001	0	.001	0	.001	0	---

TABLE 14.- WAKE SURVEY DATA; MODEL 7 - Continued

$$[\beta_{0.75R} = 27^\circ]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.283		1.221		1.163		1.102	
0.20	-0.007	0	0	0.001	0.006	0.002	0.011	0.003
.35	.012	0.003	0.026	.006	.036	.007	.045	.009
.48	.032	.008	.051	.011	.065	.013	.081	.015
.60	.050	.011	.076	.015	.096	.019	.114	.022
.71	.045	.012	.076	.017	.102	.021	.126	.025
.81	.004	.004	.038	.009	.070	.014	.100	.020
.89	-.016	.002	.017	.006	.043	.010	.071	.015
.95	-.026	0	-.001	.004	.019	.007	.040	.010
1.00	-.005	.001	-.008	0	-.006	0	-.008	0
1.05	-.001	-.001	-.002	.002	-.003	0	-.001	.001
$\frac{V/nD}{x}$	1.040		0.975		0.914		0.793	
0.20	0.015	0.003	0.019	0.004	0.021	0.004	0.025	0.004
.35	.051	.010	.059	.011	.066	.011	.078	.012
.48	.095	.017	.107	.019	.120	.020	.140	.021
.60	.135	.025	.151	.027	.170	.029	.195	.030
.71	.145	.029	.172	.032	.193	.034	.227	.036
.81	.136	.025	.168	.029	.189	.031	.220	.034
.89	.104	.020	.139	.025	.172	.029	.202	.031
.95	.065	.014	.094	.018	.131	.023	.162	.026
1.00	-.003	.001	-.001	.001	.004	.003	.003	.003
1.05	-.002	.001	-.001	.002	.001	.003	0	.001
$\frac{V/nD}{x}$	0.611		0.367					
0.20	0.028	0.003	0.034	0.003				
.35	.088	.011	.116	.015				
.48	.152	.020	.167	.025				
.60	.219	.031	.237	.040				
.71	.261	.041	.256	.051				
.81	.268	.040	.273	.053				
.89	.253	.036	.257	.046				
.95	.168	.031	-.016	.008				
1.00	0	.004	-.009	.005				
1.05	0	.002	0	.001				

TABLE 14.- WAKE SURVEY DATA; MODEL 7 - Continued

$$\left[ \beta_{0.75R} = 37^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	1.812		1.743		1.666		1.527	
0.20	0.003	0.002	0.008	0.003	0.013	0.004	0.021	0.006
.35	.023	.007	.034	.010	.044	.013	.062	.016
.48	.046	.013	.061	.017	.075	.021	.107	.027
.60	.073	.020	.096	.026	.116	.031	.158	.040
.71	.081	.022	.108	.031	.132	.038	.182	.050
.81	.046	.012	.081	.022	.113	.031	.188	.048
.89	.030	.012	.064	.019	.085	.028	.174	.046
.95	.012	.007	.041	.013	.064	.019	.125	.035
1.00	-.008	-.001	-.007	0	-.009	0	-.007	.003
1.05	0	-.001	0	0	0	0	0	.002
$\frac{V/nD}{x}$	1.461		1.309		1.234		0.940	
0.20	0.022	0.007	0.024	0.007	0.026	0.007	0.027	0.005
.35	.065	.017	.076	.018	.083	.019	.098	.018
.48	.116	.029	.138	.033	.152	.033	.176	.032
.60	.171	.043	.203	.047	.218	.049	.285	.057
.71	.195	.052	.233	.058	.252	.060	.281	.072
.81	.201	.050	.242	.057	.267	.060	.283	.071
.89	.194	.050	.232	.056	.255	.059	.286	.070
.95	.159	.039	.200	.046	.227	.050	.266	.057
1.00	0	.003	-.007	.007	0	.007	0	.015
1.05	0	.002	-.001	.003	0	.004	0	.003
$\frac{V/nD}{x}$	0.726		0.509					
0.20	0.033	0.005	0.039	0.005				
.35	.117	.020	.146	.024				
.48	.215	.040	.200	.038				
.60	.299	.058	.268	.057				
.71	.286	.069	.323	.075				
.81	.285	.075	.307	.078				
.89	.279	.079	.237	.104				
.95	.145	.086	.088	.080				
1.00	0	.025	.002	.031				
1.05	0	.005	-.005	.011				

TABLE 14.- WAKE SURVEY DATA; MODEL 7 - Continued

$$\beta_{0.75R} = 48^\circ$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
$\frac{V/nD}{x}$	2.661		2.528		2.420		2.322	
0.20	0.028	0.016	0.029	0.018	0.031	0.018	0.031	0.018
.35	.054	.028	.065	.031	.073	.033	.077	.034
.48	.069	.031	.087	.040	.099	.045	.110	.049
.60	.097	.039	.123	.051	.152	.059	.173	.067
.71	.099	.040	.128	.059	.170	.070	.195	.081
.81	.054	.021	.102	.044	.164	.061	.192	.078
.89	.045	.023	.085	.042	.151	.058	.177	.077
.95	.026	.013	.057	.029	.114	.042	.141	.057
1.00	0	0	.020	0	0	.006	-.025	.003
1.05	0	0	0	0	0	.002	0	0
$\frac{V/nD}{x}$	2.024		1.821		1.615		1.412	
0.20	0.032	0.016	0.028	0.014	0.027	0.012	0.029	0.010
.35	.090	.036	.098	.035	.105	.034	.109	.031
.48	.148	.057	.169	.058	.183	.056	.196	.053
.60	.224	.080	.245	.082	.274	.084	.347	.097
.71	.247	.097	.279	.102	.320	.114	.279	.103
.81	.258	.096	.302	.108	.338	.118	.265	.105
.89	.255	.097	.299	.107	.334	.119	.286	.109
.95	.226	.081	.272	.091	.313	.099	.241	.103
1.00	-.016	.012	-.018	.013	-.008	.018	-.018	.035
1.05	-.007	.006	-.008	.005	-.002	0	-.005	.006
$\frac{V/nD}{x}$	1.205		0.905		0.711		0.599	
0.20	0.027	0.010	0.045	0.010	0.035	0.009	0.040	0.009
.35	.120	.032	.158	.037	.167	.039	.169	.038
.48	.213	.059	.163	.053	.163	.056	.169	.059
.60	.278	.084	.310	.089	.270	.091	.249	.090
.71	.271	.097	.333	.104	.386	.118	.420	.122
.81	.312	.109	.349	.108	.291	.099	.293	.102
.89	.264	.107	.217	.107	.182	.105	.163	.102
.95	.141	.108	.082	.101	.085	.106	.083	.098
1.00	.009	.058	.030	.087	.067	.102	.066	.100
1.05	-.013	.015	-.014	.058	0	.087	.025	.087

TABLE 14.- WAKE SURVEY DATA; MODEL 7 - Concluded

$$\left[ \beta_{0.75R} = 60^\circ \right]$$

Thrust and torque	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	
$\frac{V/nD}{x}$	3.677		3.563		3.408		3.265		
0.20	0.038	0.050	0.042	0.048	0.033	0.045	0.034	0.042	
.35	.137	.100	.143	.098	.137	.095	.138	.093	
.48	.183	.125	.191	.127	.197	.127	.201	.127	
.60	.255	.148	.257	.152	.279	.156	.281	.159	
.71	.249	.153	.262	.162	.285	.167	.279	.175	
.81	.232	.132	.242	.149	.281	.156	.285	.166	
.89	.198	.133	.222	.147	.276	.158	.283	.169	
.95	.131	.092	.161	.108	.217	.120	.255	.134	
1.00	-.021	.004	-.050	.008	-.027	.015	-.017	.017	
1.05	-.011	.007	-.031	0	0	.004	-.009	0	
$\frac{V/nD}{x}$	3.113		2.992		2.840		2.546		
0.20	0.029	0.039	0.031	0.037	0.024	0.033	0.013	0.028	
.35	.136	.089	.143	.087	.142	.083	.132	.069	
.48	.212	.126	.223	.125	.222	.123	.215	.109	
.60	.297	.161	.312	.162	.312	.161	.306	.153	
.71	.302	.182	.324	.184	.333	.186	.343	.193	
.81	.315	.175	.336	.182	.354	.191	.363	.201	
.89	.311	.179	.332	.186	.361	.193	.372	.206	
.95	.275	.150	.294	.155	.349	.165	.368	.173	
1.00	-.023	.020	-.028	.021	-.019	.026	-.031	.031	
1.05	-.016	.009	-.007	.008	-.007	.009	-.027	.008	
$\frac{V/nD}{x}$	2.289		1.984		1.711		1.421		
0.20	-.042	0.017	0.006	0.020	0.026	0.022	0.041	0.023	
.35	.057	.049	.044	.042	.046	.041	.049	.046	
.48	.206	.097	.118	.079	.117	.072	.163	.081	
.60	.338	.156	.316	.139	.323	.133	.302	.128	
.71	.272	.171	.269	.151	.282	.145	.257	.133	
.81	.303	.172	.273	.153	.261	.143	.265	.138	
.89	.304	.179	.201	.153	.168	.141	.155	.135	
.95	.285	.151	.126	.139	.085	.145	.101	.156	
1.00	-.012	.044	.003	.090	.028	.124	.100	.157	
1.05	.009	.011	0	.014	-.024	.045	-.030	.084	
$\frac{V/nD}{x}$	1.277		0.998						
0.20	0.040	0.022	0.045	0.020					
.35	.052	.046	.079	.046					
.48	.159	.081	.115	.074					
.60	.324	.131	.323	.131					
.71	.281	.142	.323	.158					
.81	.248	.131	.228	.131					
.89	.185	.139	.194	.149					
.95	.127	.156	.154	.154					
1.00	.128	.158	.149	.168					
1.05	-.019	.095	.028	.124					



Figure 1.- Forms of model blades tested.

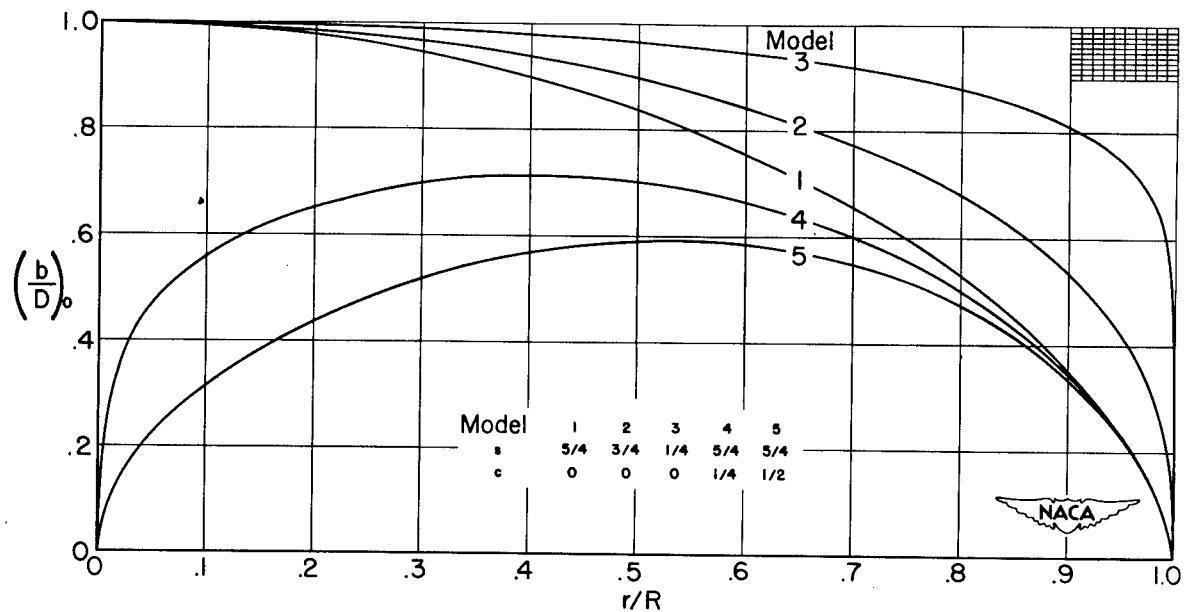


Figure 2.- Basic width curves.  $(b/D)_0 = \sin^s \theta \cos^c \theta$ ;  $\theta = \cos^{-1} (r/R)$ .

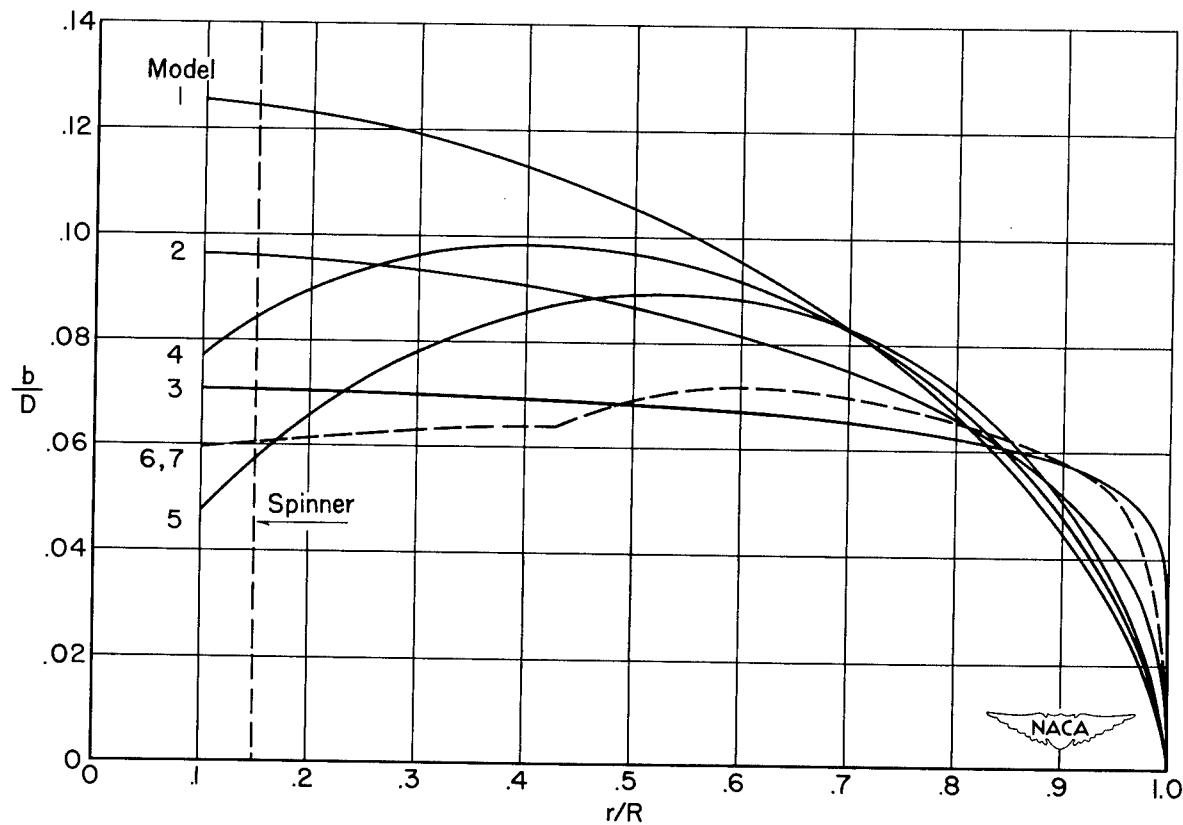


Figure 3.- Adjusted width curves. A.F. = 6250  $\int_{0.15}^{1.0} \left(\frac{b}{D}\right) \left(\frac{r}{R}\right)^3 d\left(\frac{r}{R}\right) = 92.4$ .  
(All models.)

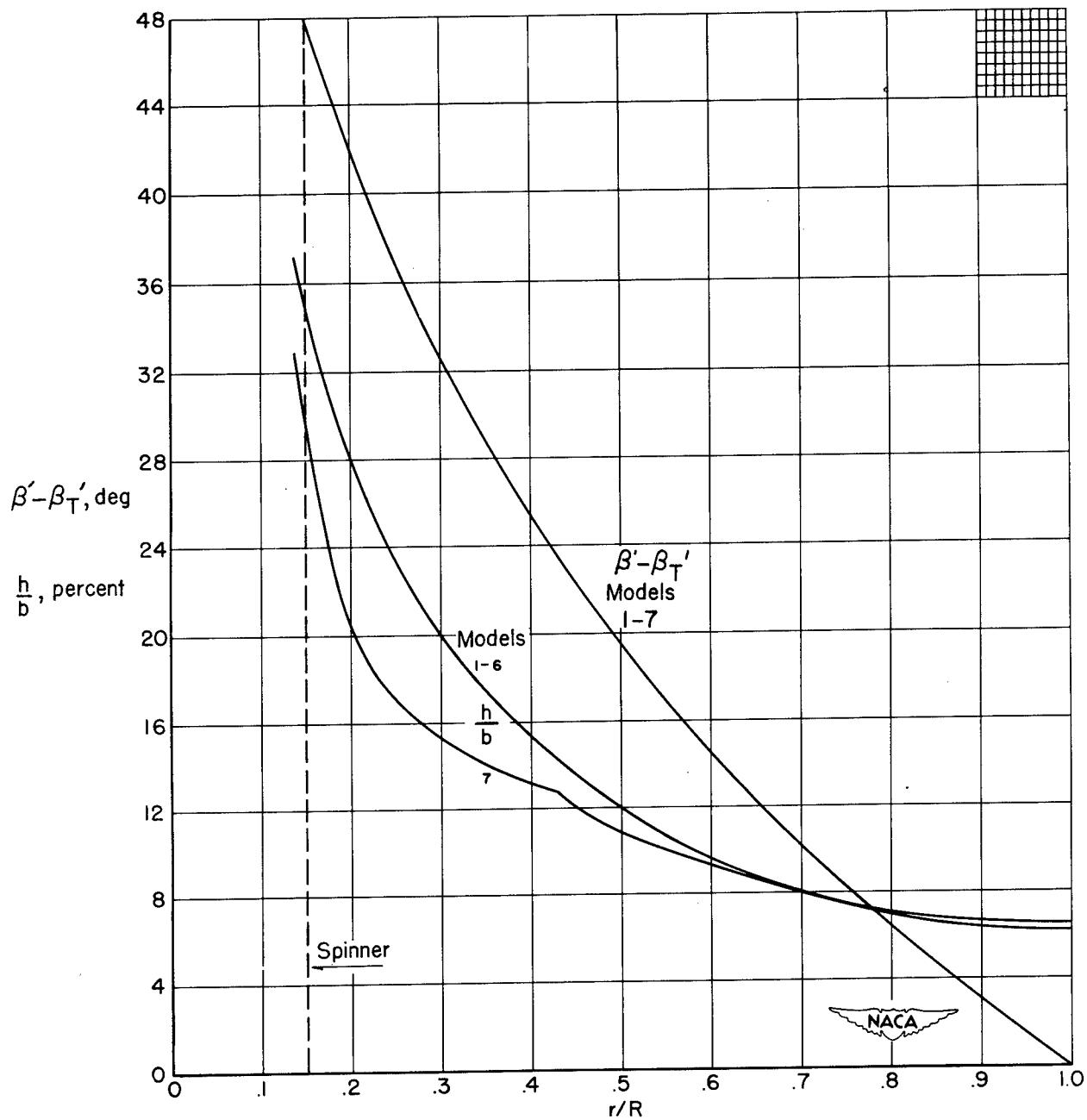


Figure 4.- Thickness and twist curves.

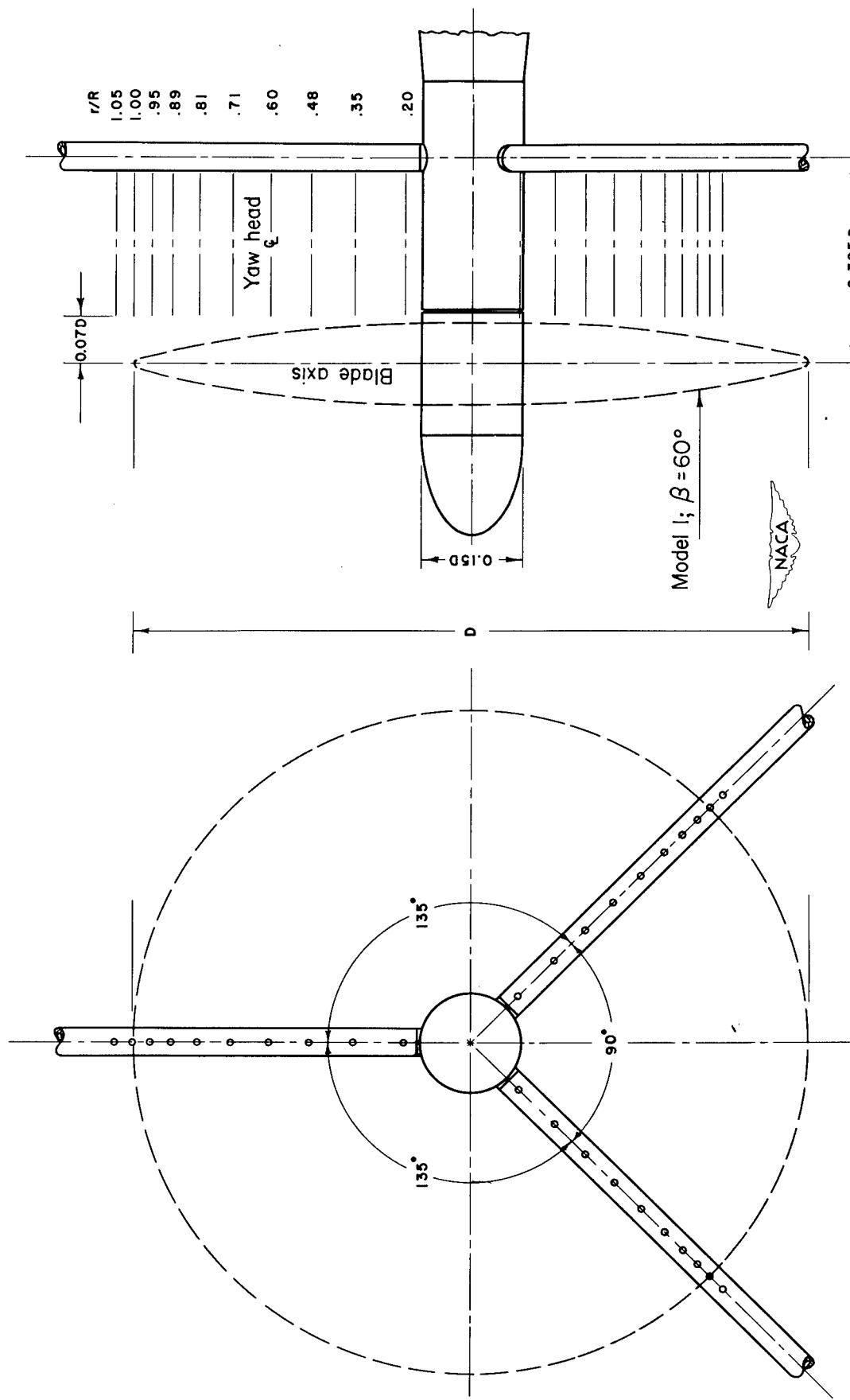


Figure 5.- General arrangement of survey apparatus.  $D = 33.6$  inches.

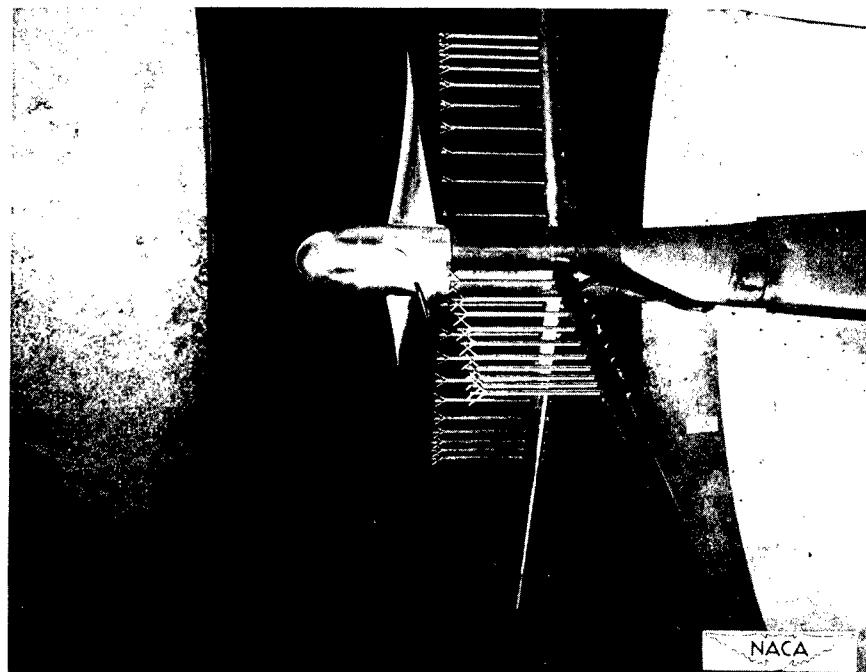


Figure 6.- Installation of total-head and yaw tubes.

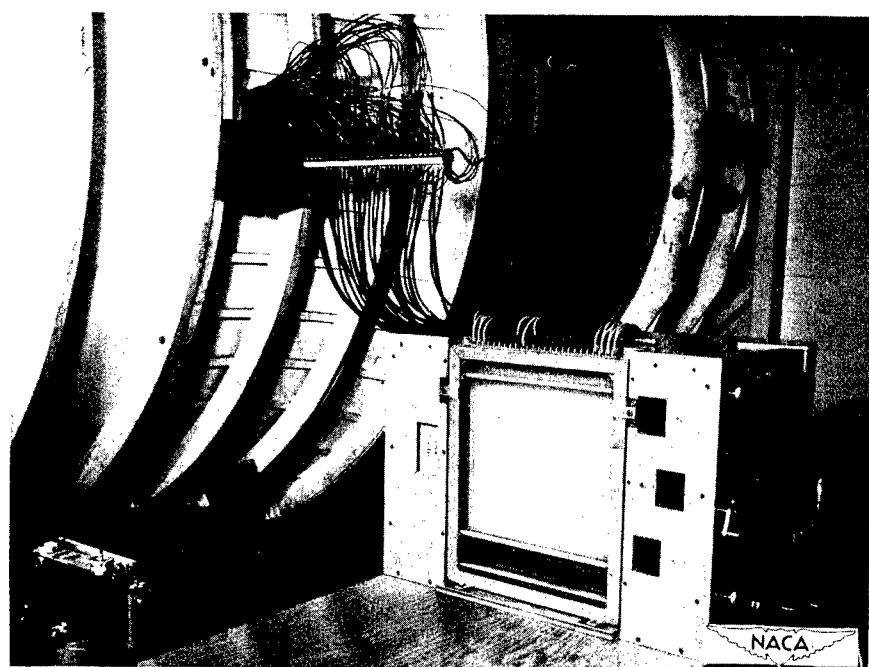


Figure 7.- General arrangement of pressure-recording equipment.

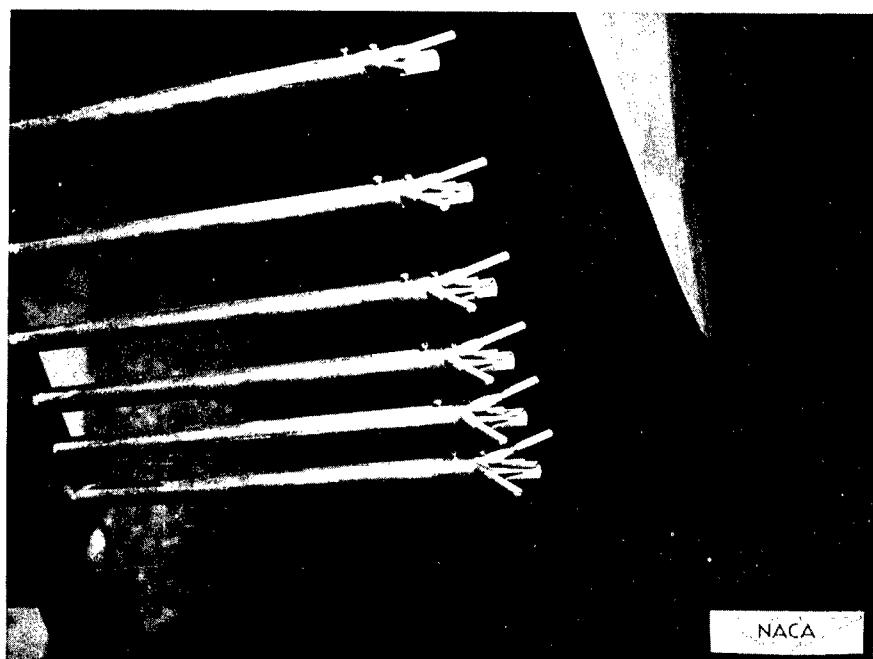
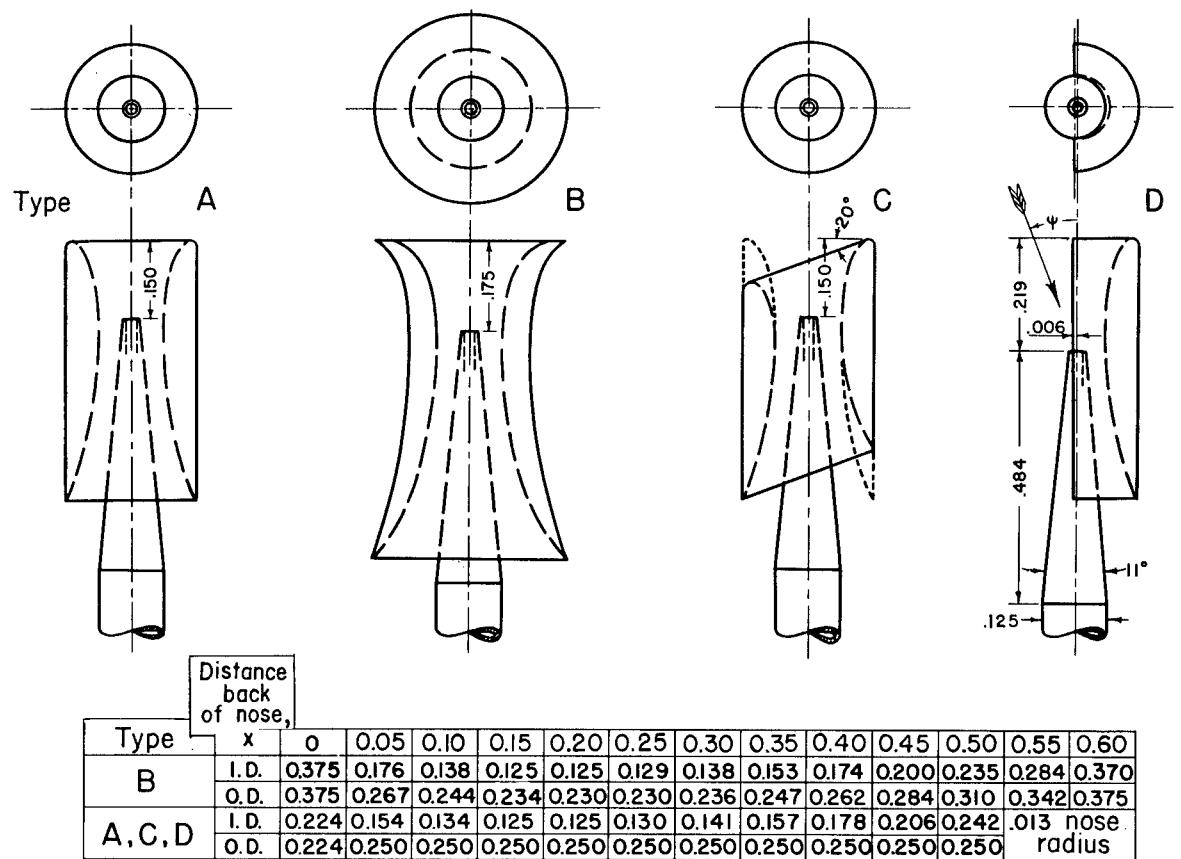


Figure 8.- Close-up of total-head and yaw tubes.



All dimensions are in inches.

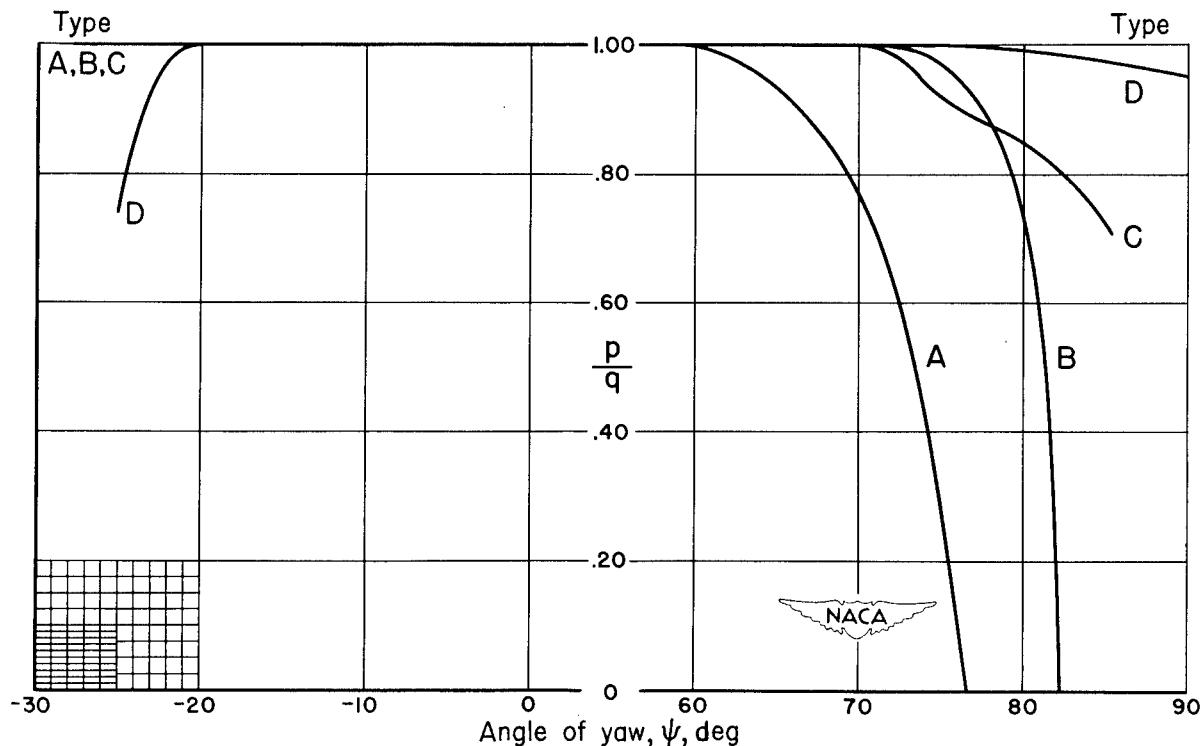


Figure 9. - Shielded total-head tubes.

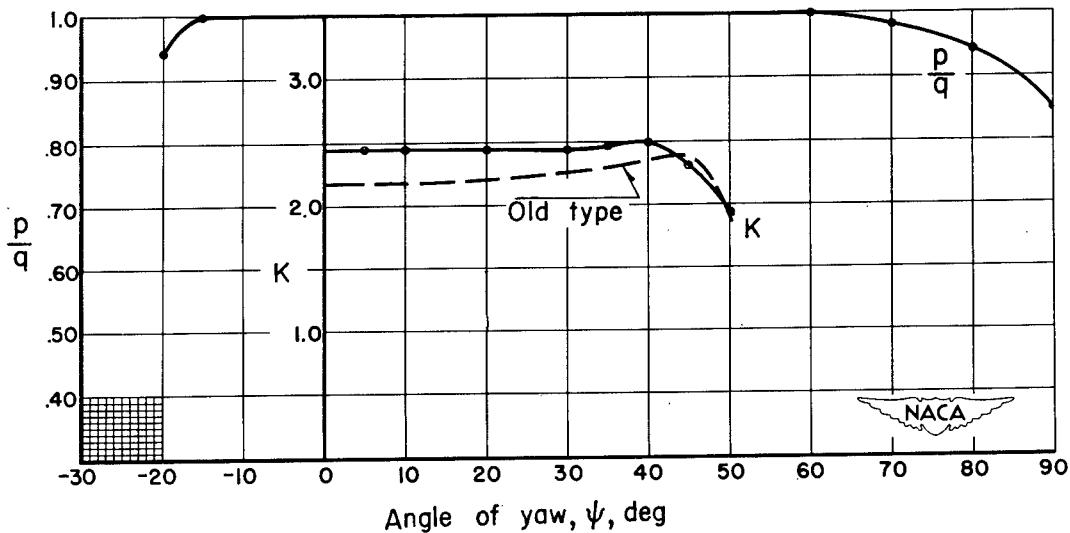
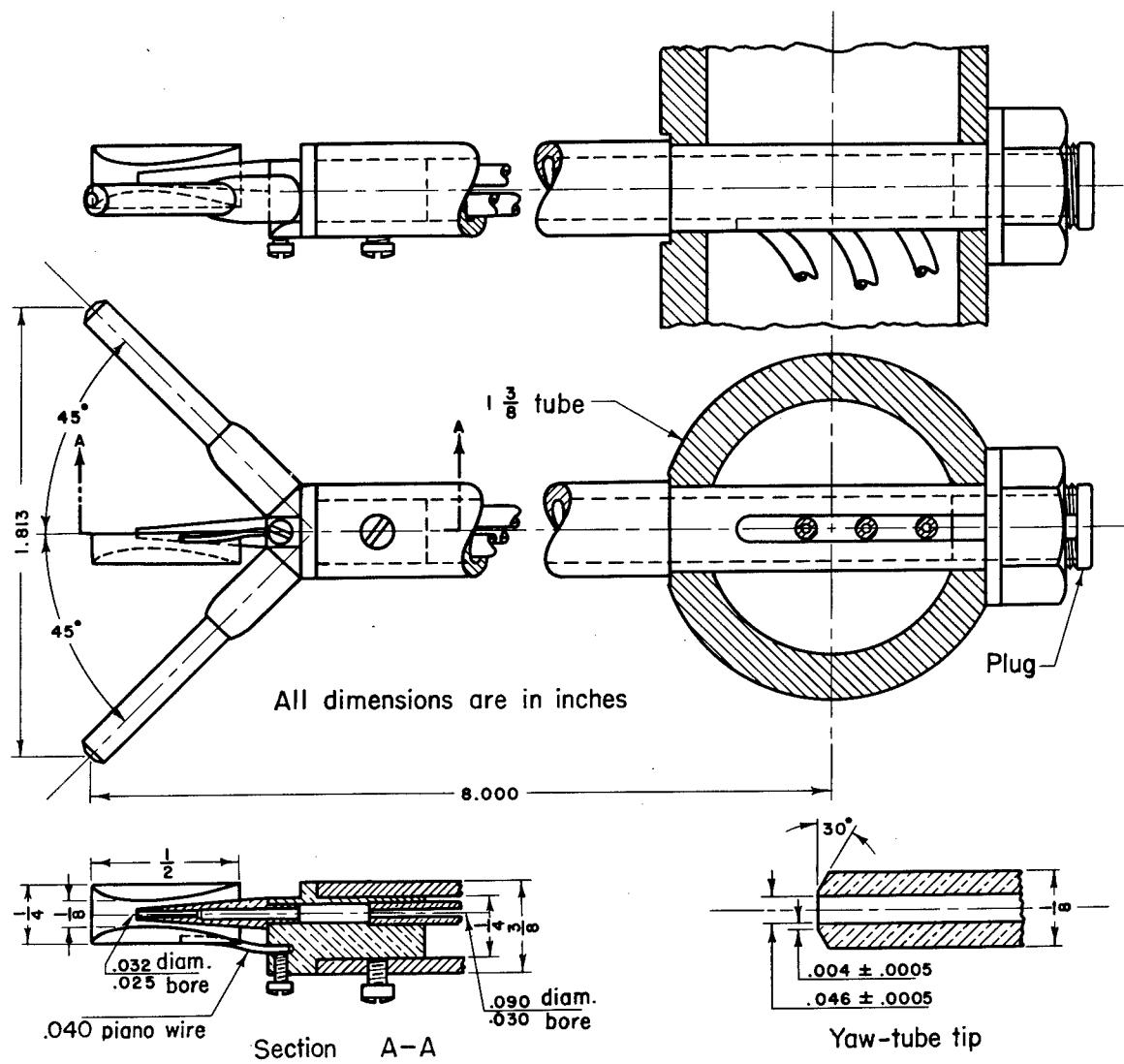


Figure 10.- Yaw-head details and calibration.  $K = \frac{p_Y}{q \sin 2\psi}$ .

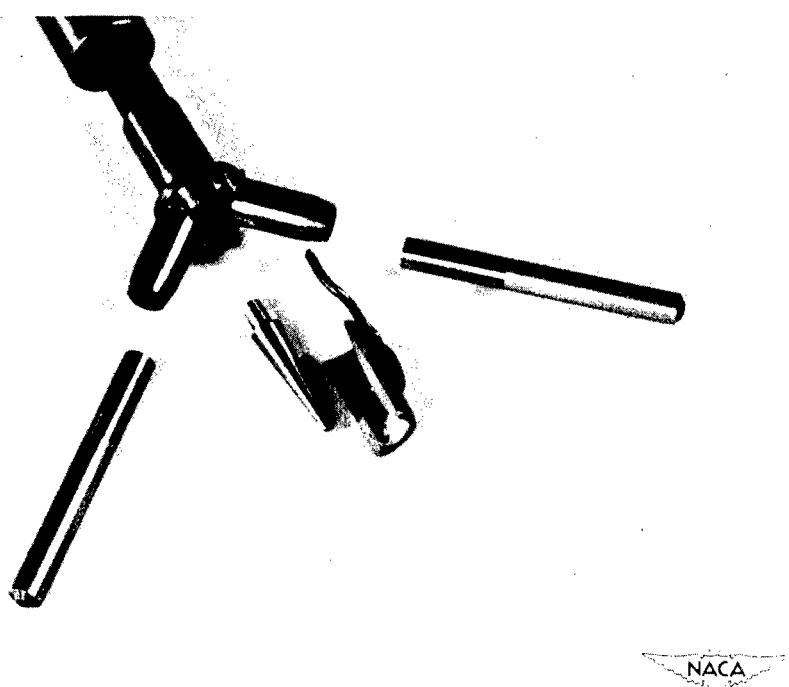


Figure 11.- Component parts of total-head and yaw tube.

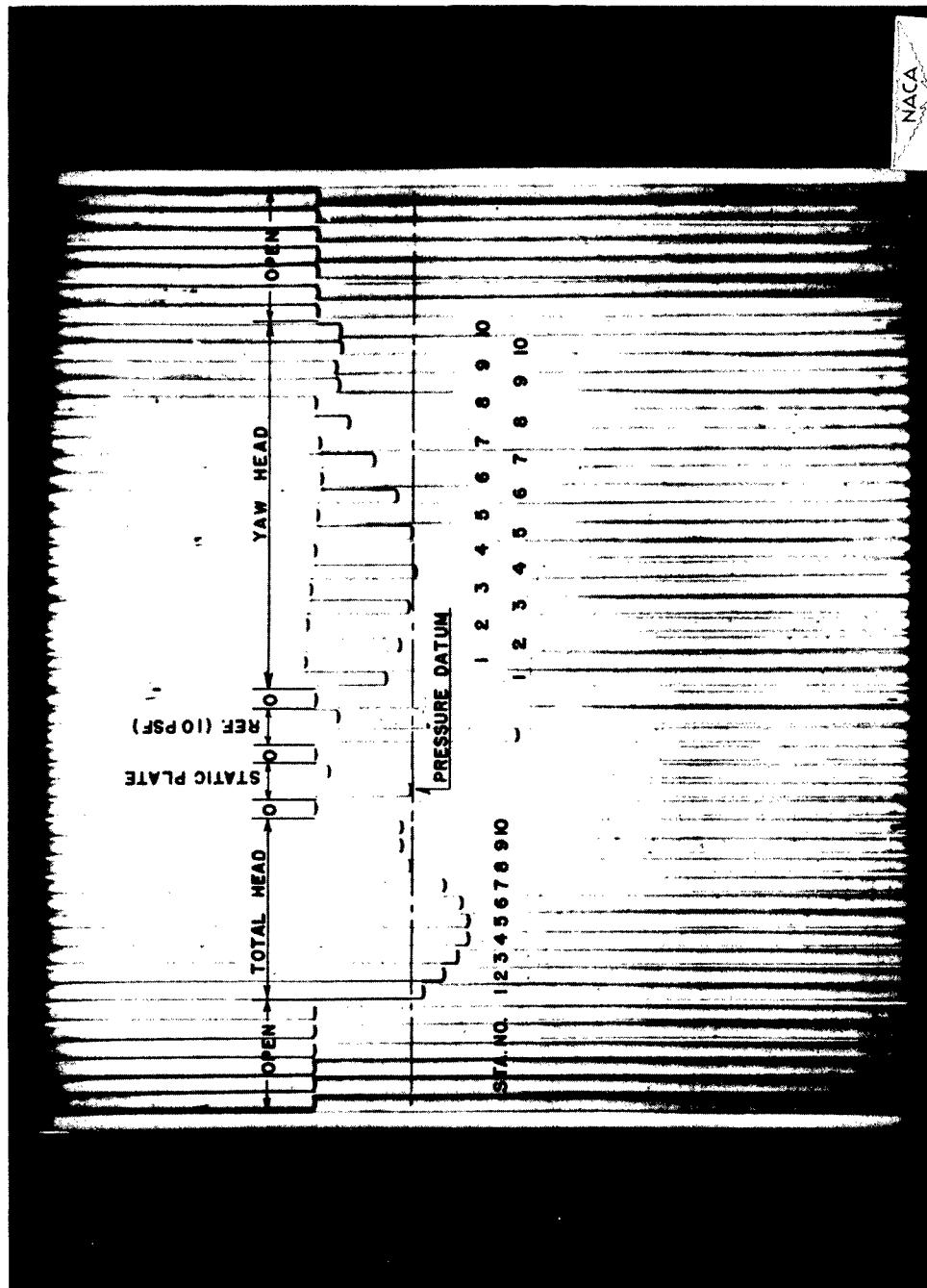


Figure 12. - Sample record.

RECORD NO. <u>F-6-13</u>										
MODEL	<u>5</u> $B_{0.75R} \underline{37}$ DEG,									
TESTED	<u>1 Feb. 46</u> <u>RECORDED 26 Mar. 46</u> <u>COMPUTED 5 Apr. 46</u>									
HEAD NO.	1	2	3	4	5	6	7	8	9	10
$P_{T1}$	.161	.403	.562	.686	.686	.608	.405	.006	-.099	-.098
$P_{T0}$	-.095	-.098	-.105	-.102	-.099	-.105	-.098	-.104	-.099	-.098
$\Delta P_T$	.256	.501	.667	.788	.785	.713	.503	.110	0	0
$P_U$	-.289	-.127	-.024	.053	.007	-.173	-.437	-.739	-.857	-.824
$P_D$	-.1295	-.1217	-.1178	-.1129	-.1101	-.1054	-.1076	-.1128	-.887	-.844
$P_{Y0}$	.946	1.090	1.154	1.182	1.108	.881	.639	.389	.030	.020
$\Delta P_Y$	-.003	+.009	-.004	-.006	-.002	+.001	-.003	+.003	+.006	+.003
$P_Y$	.943	1.099	1.150	1.176	1.106	.882	.636	.392	.036	.023
$1/K$	.435	.429	.424	.420	.420	.417	.417	.406	.405	.413
$(P_Y/K)^2$	.1681	.2223	.2378	.2439	.2158	.1353	.0702	.0253	—	—
$1/4r_1^2$	.222	.202	.190	.183	.183	.187	.202	.237	—	—
$E_1$	.037	.045	.045	.045	.039	.025	.015	.006	—	—
$\Delta P_1$	.219	.456	.622	.743	.746	.688	.488	.104	—	—
$1/4r_2^2$	.226	.205	.193	.186	.185	.189	.203	.238	—	—
$E_2$	.038	.046	.046	.046	~ Some os E, ~	~ Some os E, ~	—	—	—	—
$\Delta P_2$	.218	.455	.621	.742	.746	.688	.488	.104	0	0
$X$	.20	.35	.48	.60	.71	.81	.89	.95	1.00	1.05
$C_X$	.139	.243	.339	.416	.493	.562	.618	.659	—	—
$dC_T/dX$	.030	.111	.207	.309	.368	.387	.302	.069	0	0
$X^2/K$	.0174	.0528	.0974	.151	.212	.273	.330	.367	.405	.456
$R_Y X^2/K$	.0164	.0580	.1120	.1776	.2345	.2408	.2099	.1439	.0146	.0105
$dC_Q/dX$	.0057	.0201	.0389	.0616	.0814	.0836	.0728	.0499	.0051	.0036
$S.P. 4.53 \text{ PSF}$	$\Delta P_T = P_{T1} - P_{T0}$	$P_{Y0} = P_U - P_D$	$C_{T0} = .1792$							
$\sigma 0.960$	$\Delta P_1 = \Delta P_T - E_1$	$P_Y = P_{Y0} + \Delta P_Y$	$\Delta C_T = .0009$							
$V 64.4 \text{ FPS}$	$\Delta P_2 = \Delta P_T - E_2$	$E = (1/4r^2)(P_Y/K)^2$	$C_T = .1783$							
$n 24.48 \text{ RPS}$	$(1/4r^2) \text{ FROM CHART}$									
$D 2.80 \text{ FT}$	$dC_T/dX = \Delta P_1 X$	$dC_Q/dX = (P_Y X^2/K) C_2$								
$V/nD 0.940$	$C_1 = \frac{\pi}{4} \left( \frac{V}{nD} \right)^2 = 0.7854 (.940)^2 = 0.694$		$C_Q = .03976$							
	$C_2 = \frac{\pi}{8} \left( \frac{V}{nD} \right)^2 = 0.3927 (.940)^2 = 0.347$		$C_P = .2498$							
	$C_T = C_{T0} - \Delta C_T$	$C_P = 2\pi C_Q$								

Figure 13.- Sample computation sheet.

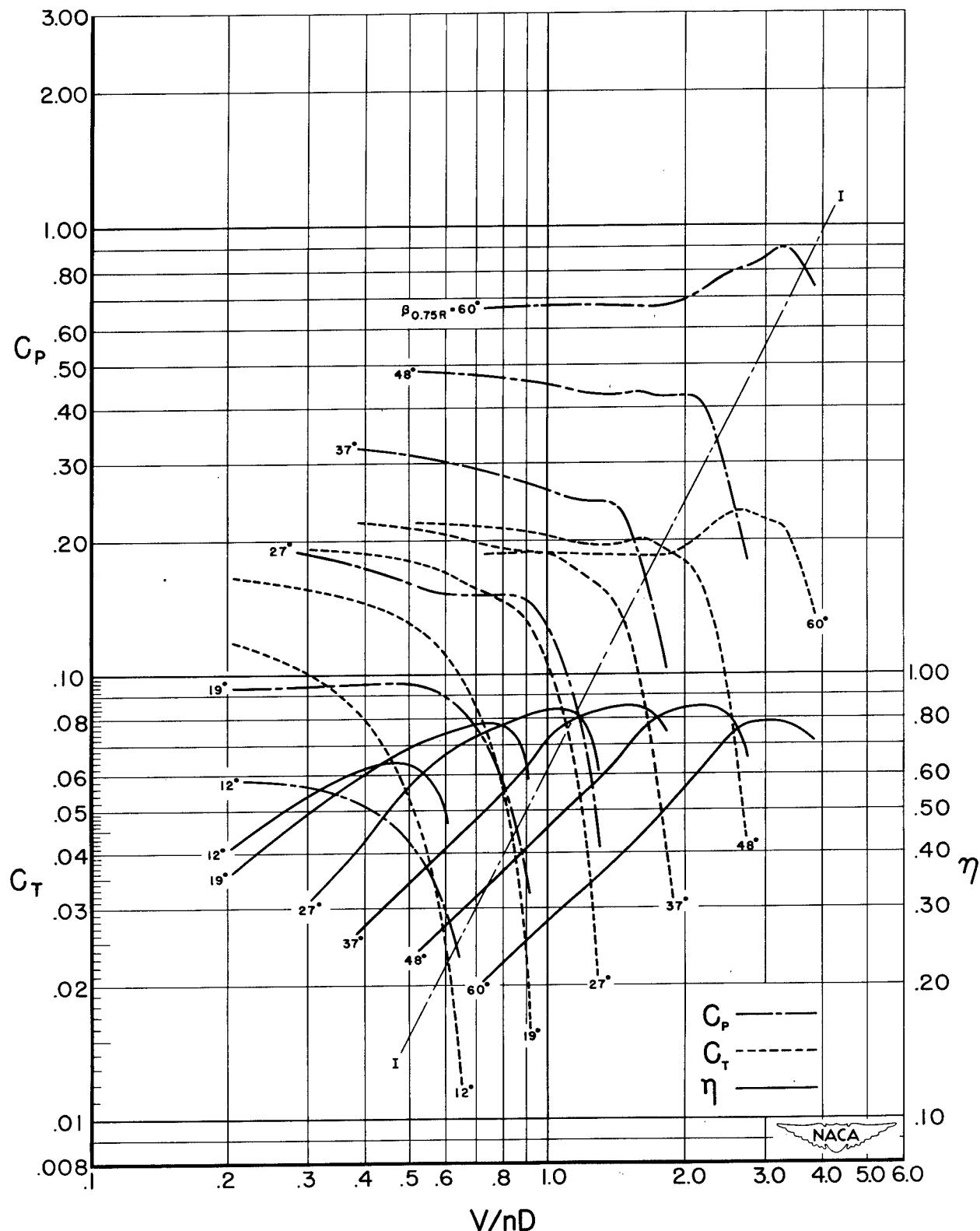


Figure 14.- Characteristics of model 1.

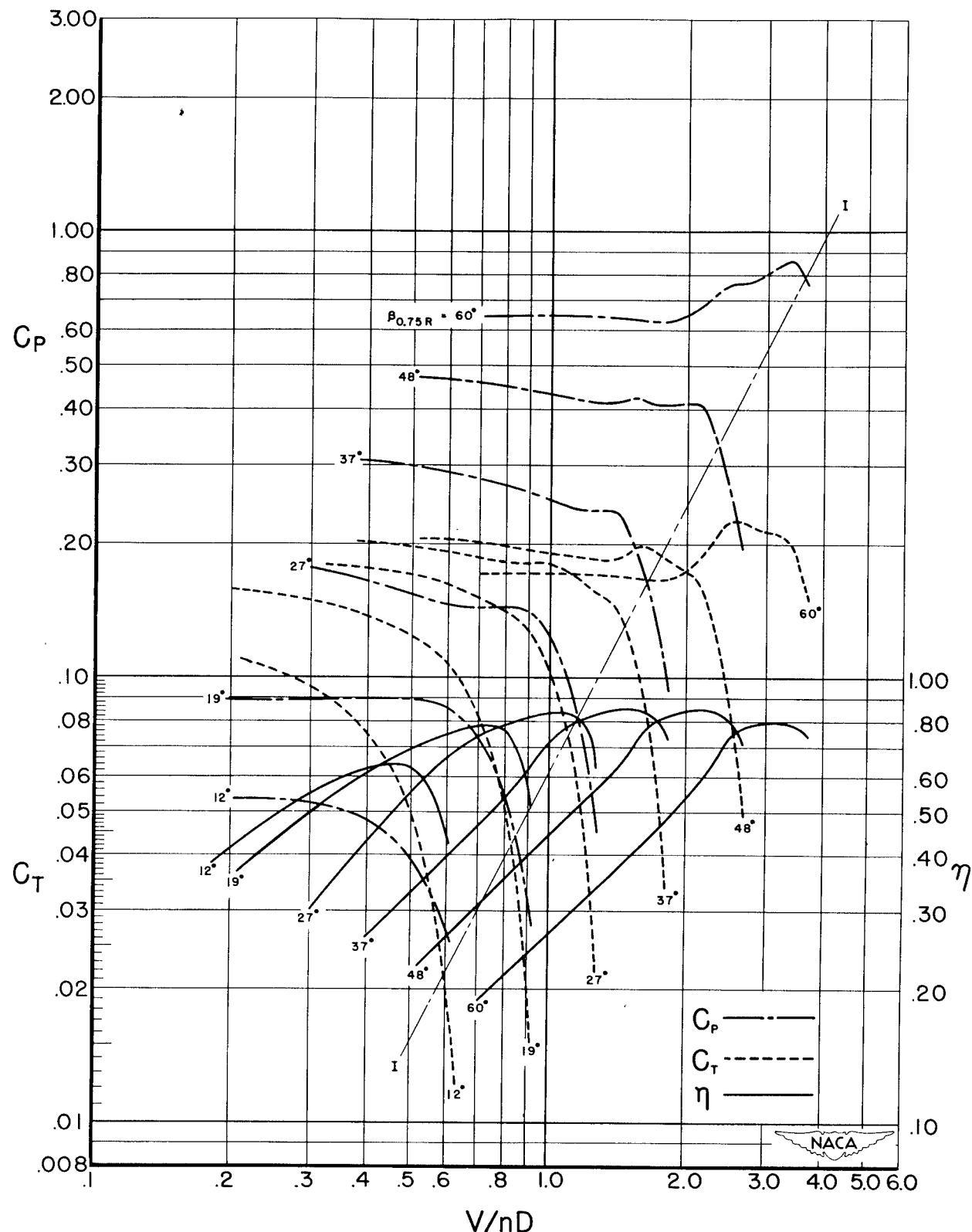


Figure 15.- Characteristics of model 2.

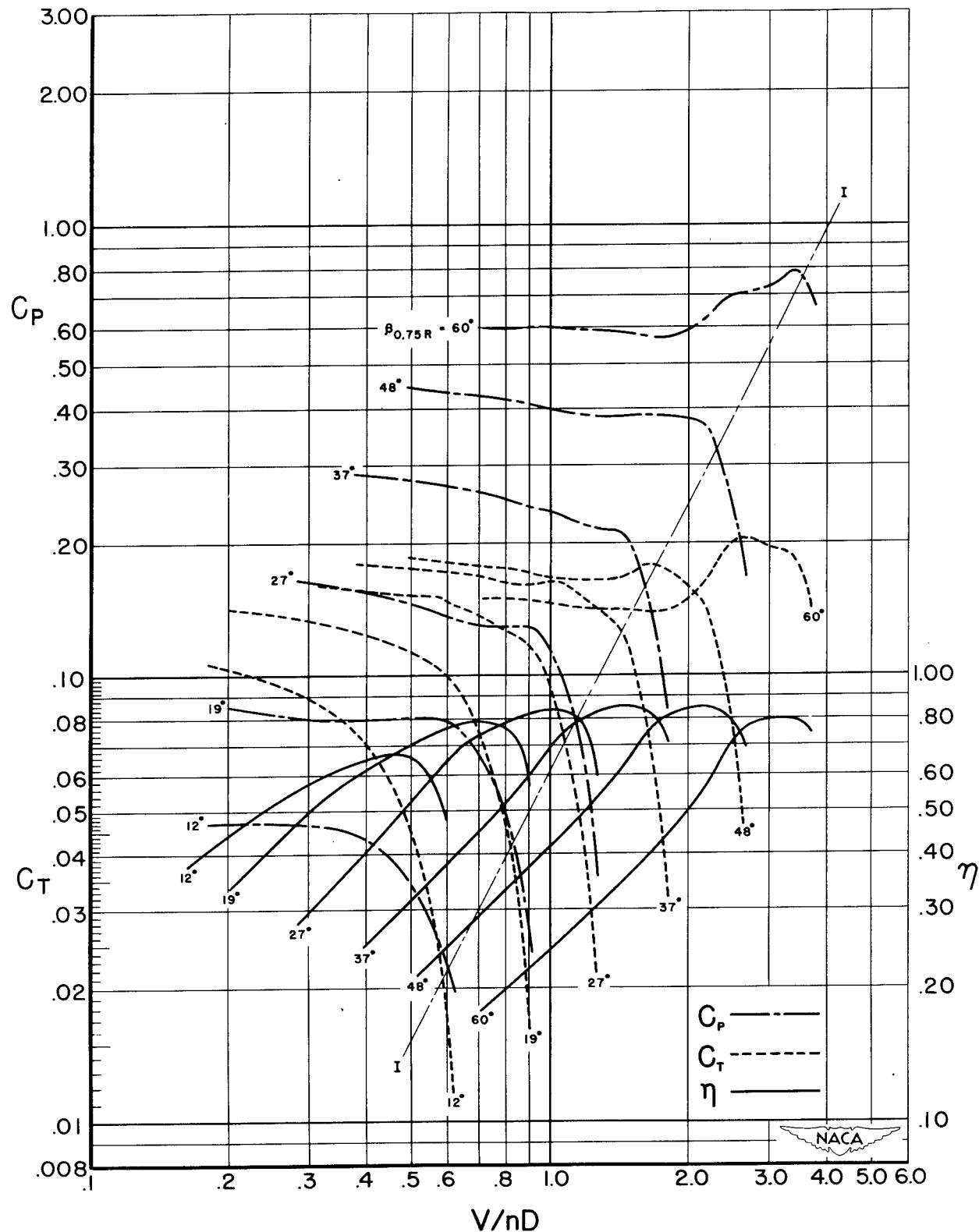


Figure 16.- Characteristics of model 3.

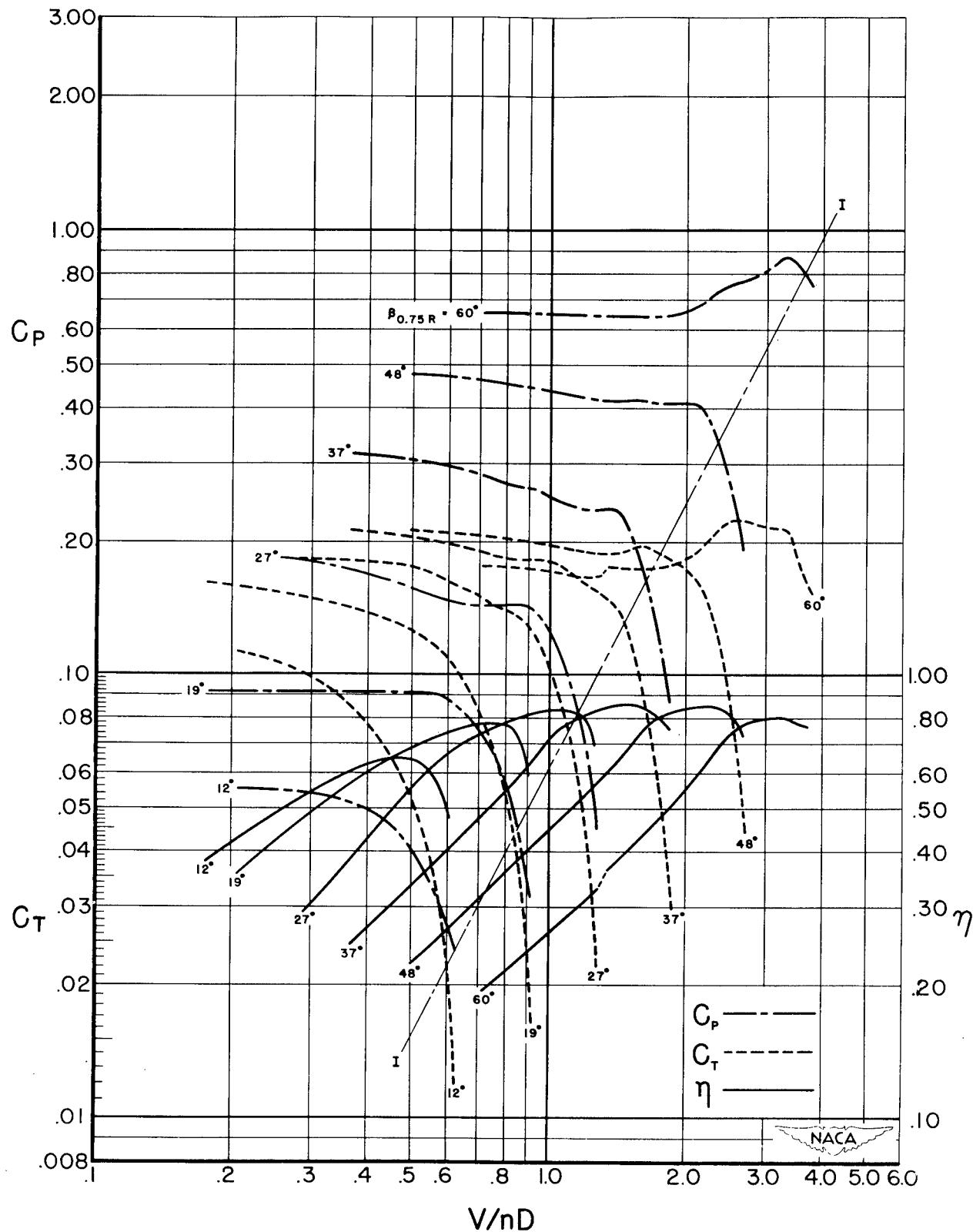


Figure 17.- Characteristics of model 4.

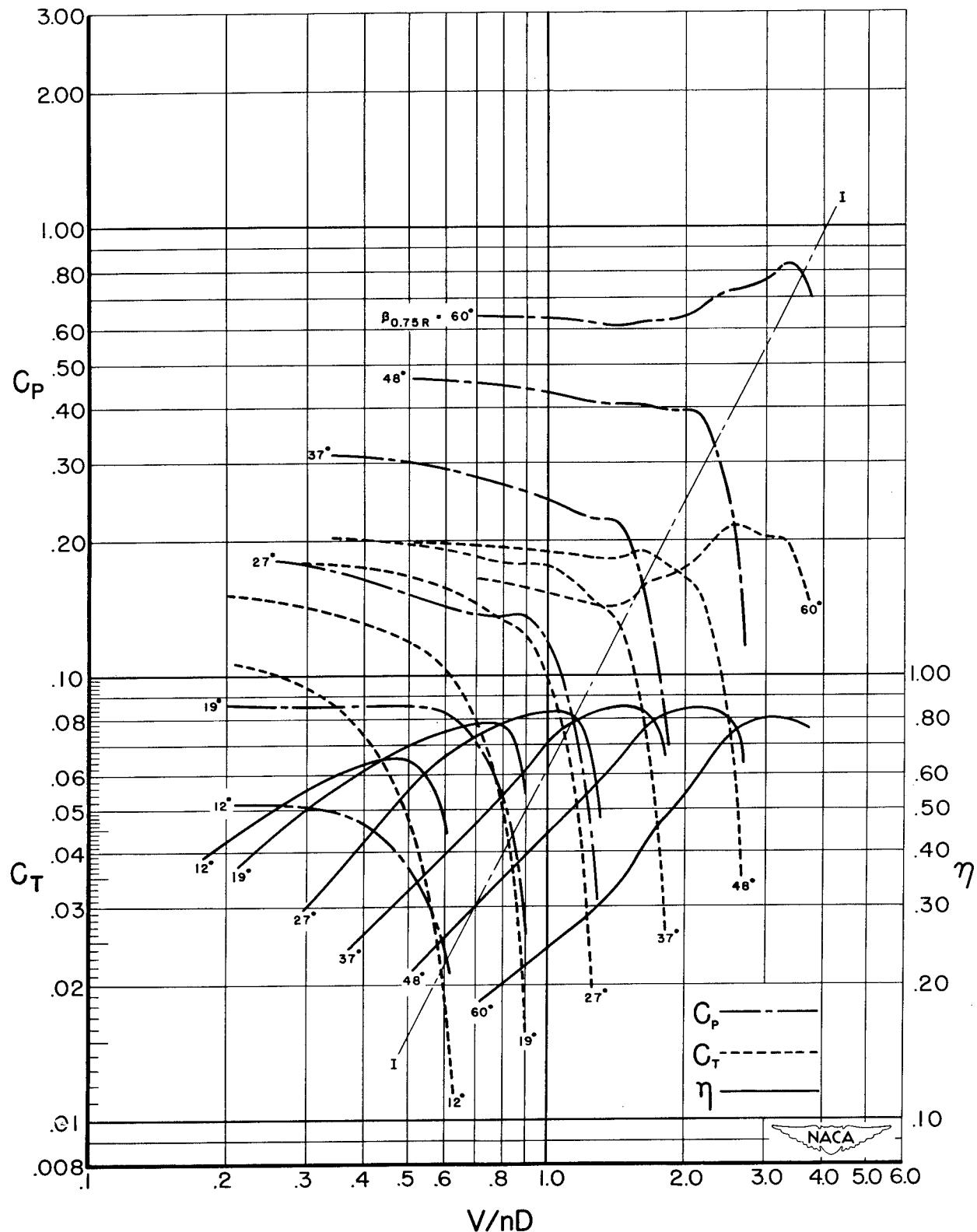


Figure 18.- Characteristics of model 5.

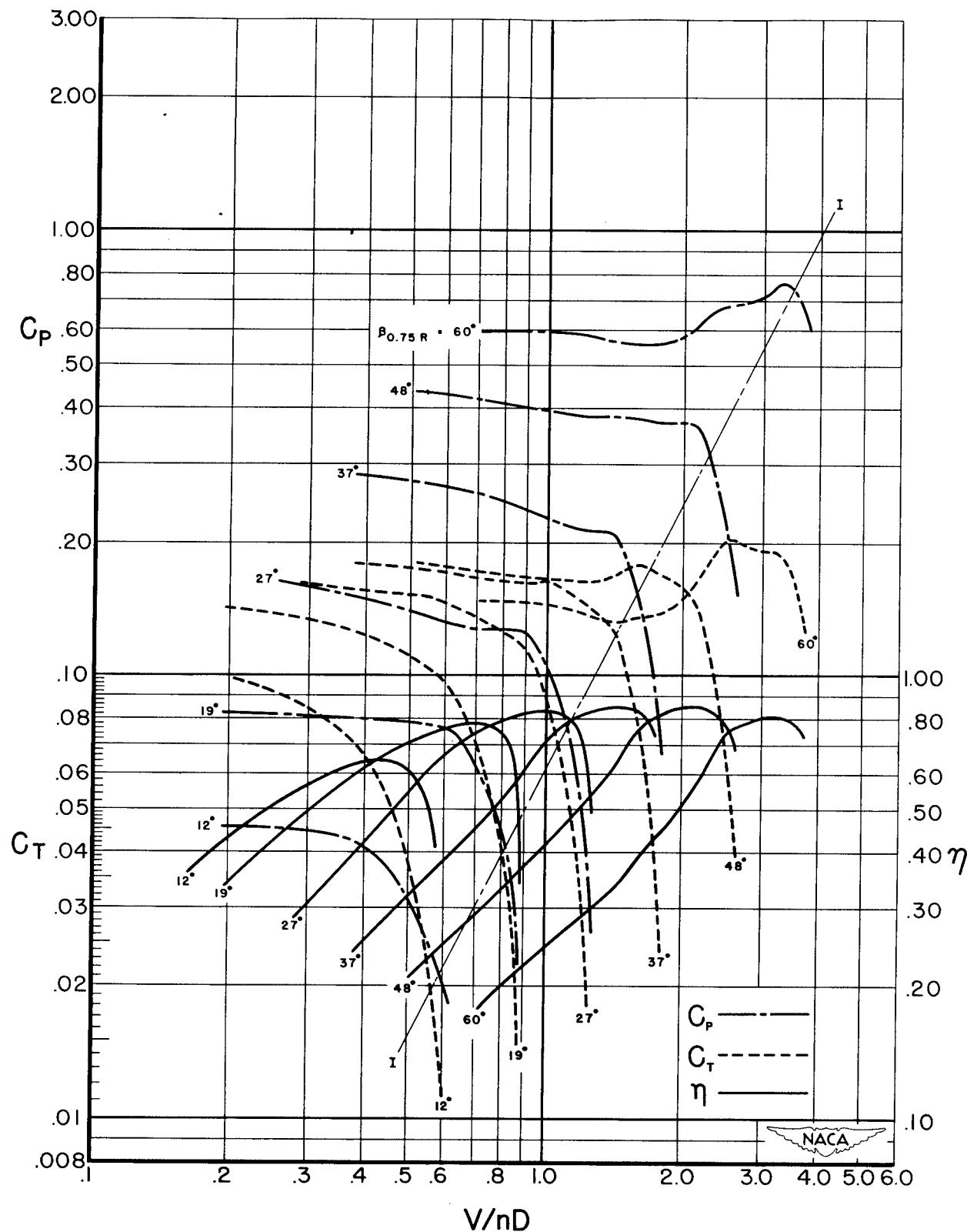


Figure 19.- Characteristics of model 6.

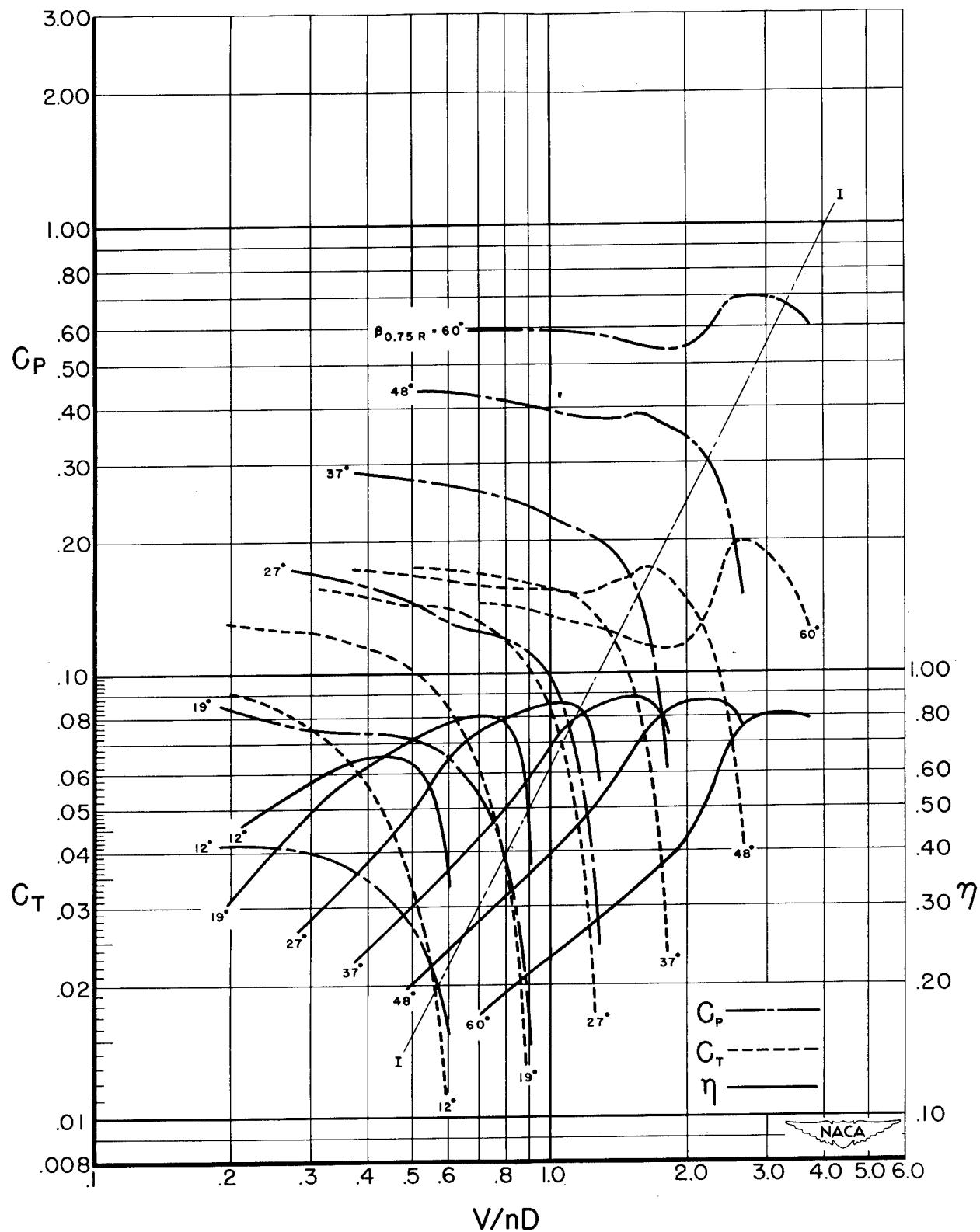


Figure 20.- Characteristics of model 7.

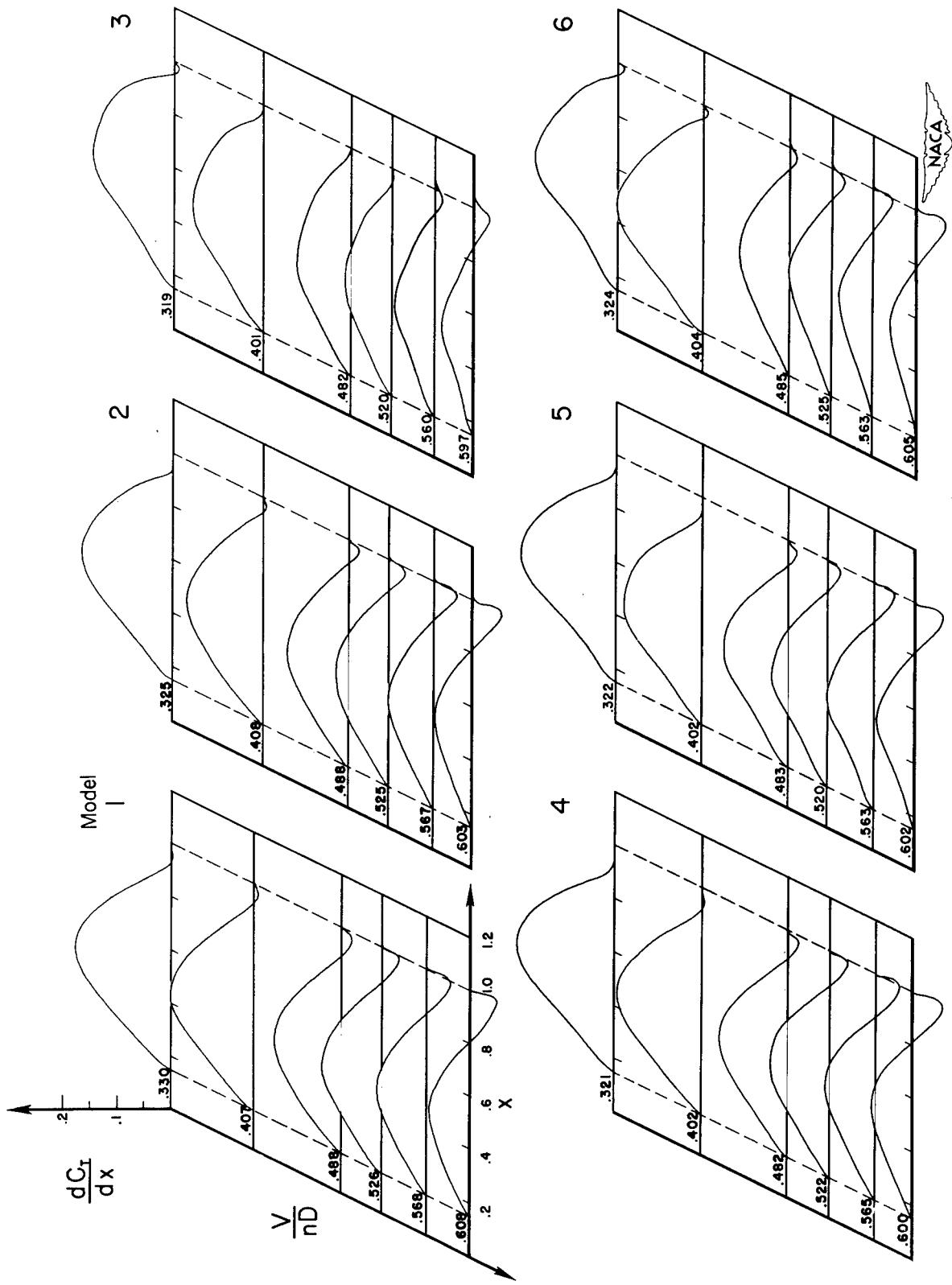


Figure 21. - Thrust grading curves.  $\beta 0.75R = 12^\circ$ .

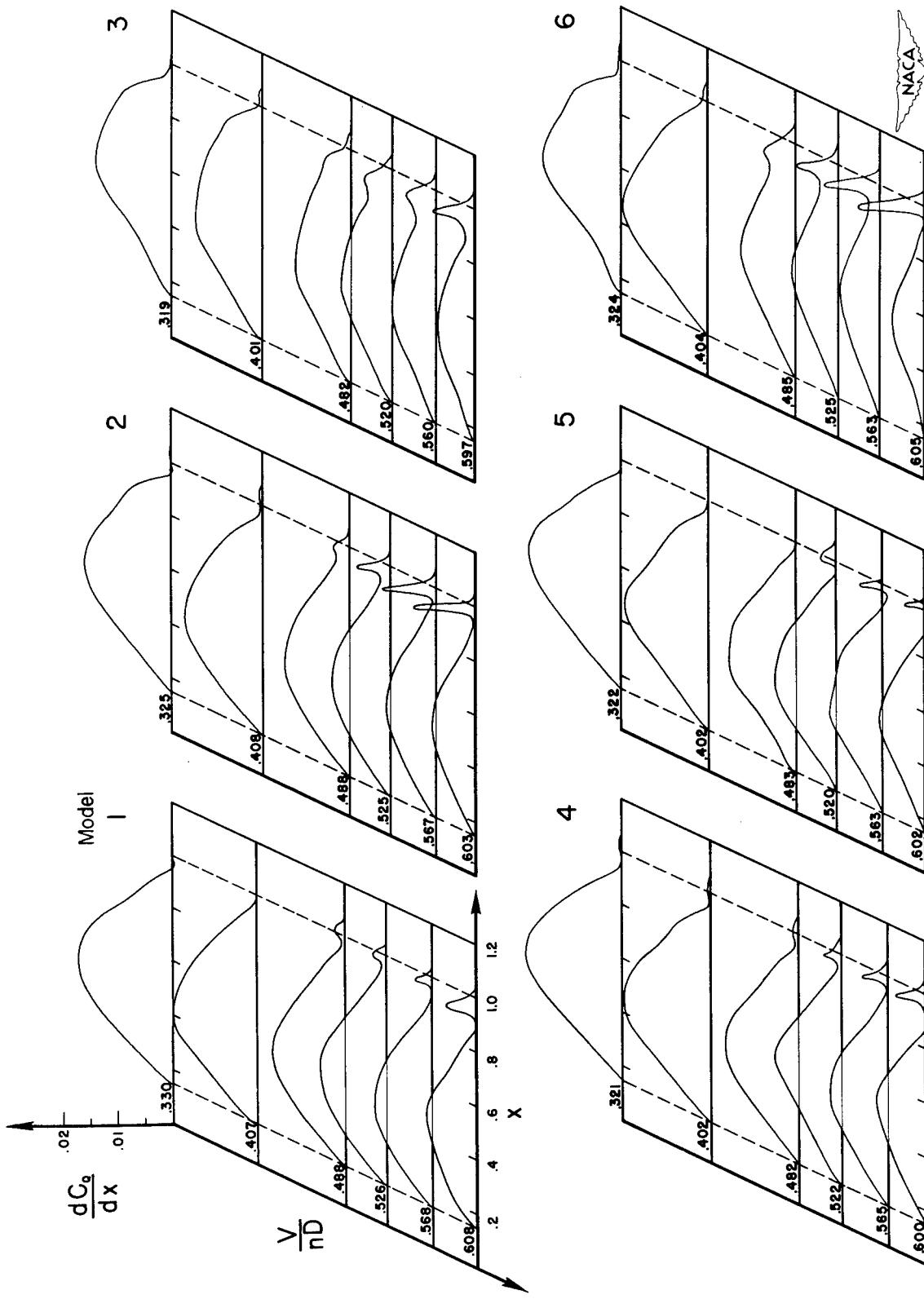
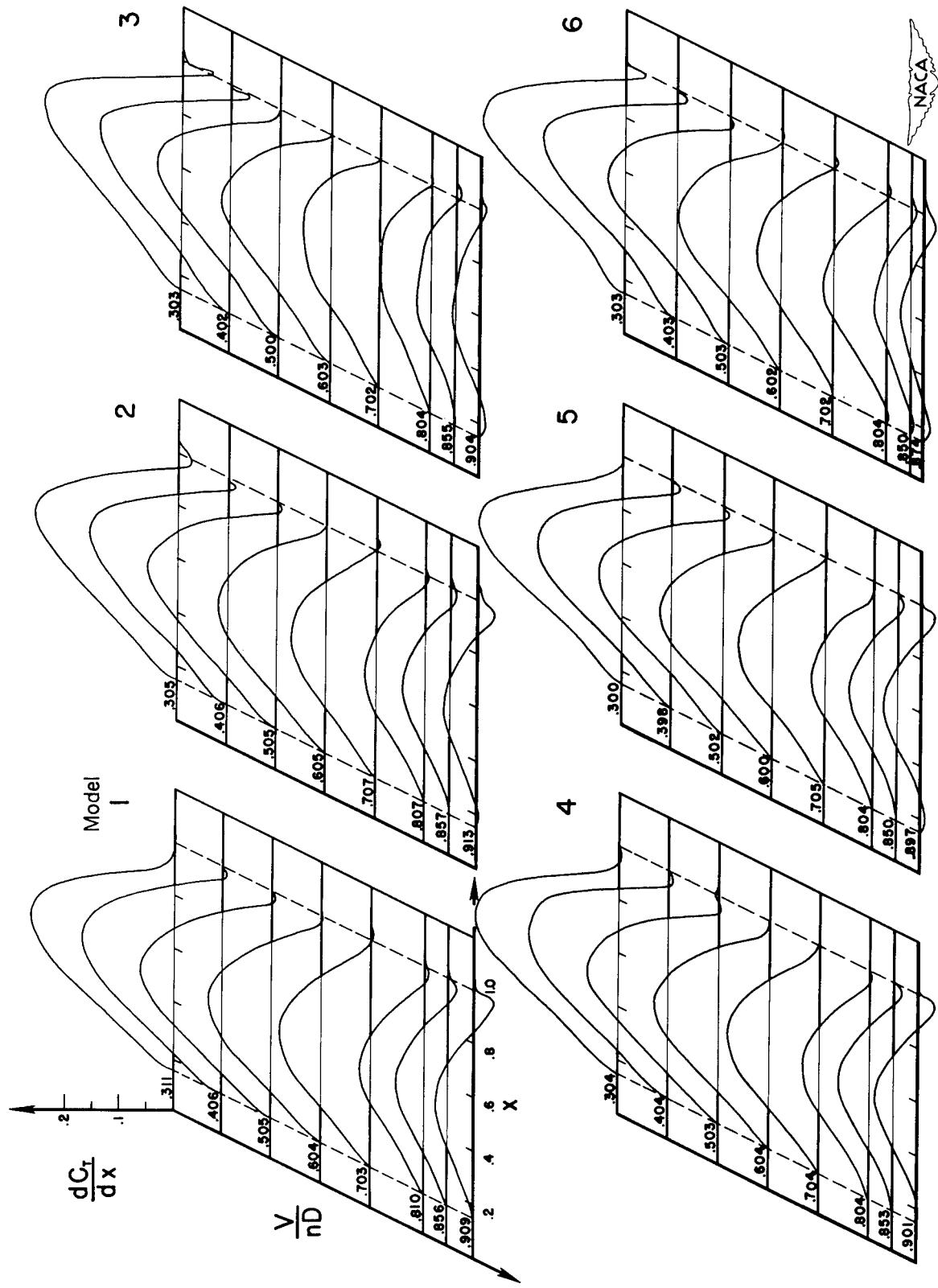


Figure 22. - Torque grading curves.  $\beta 0.75R = 12^\circ$ .

Figure 23. - Thrust grading curves.  $\beta = 0.75R = 190^\circ$ .

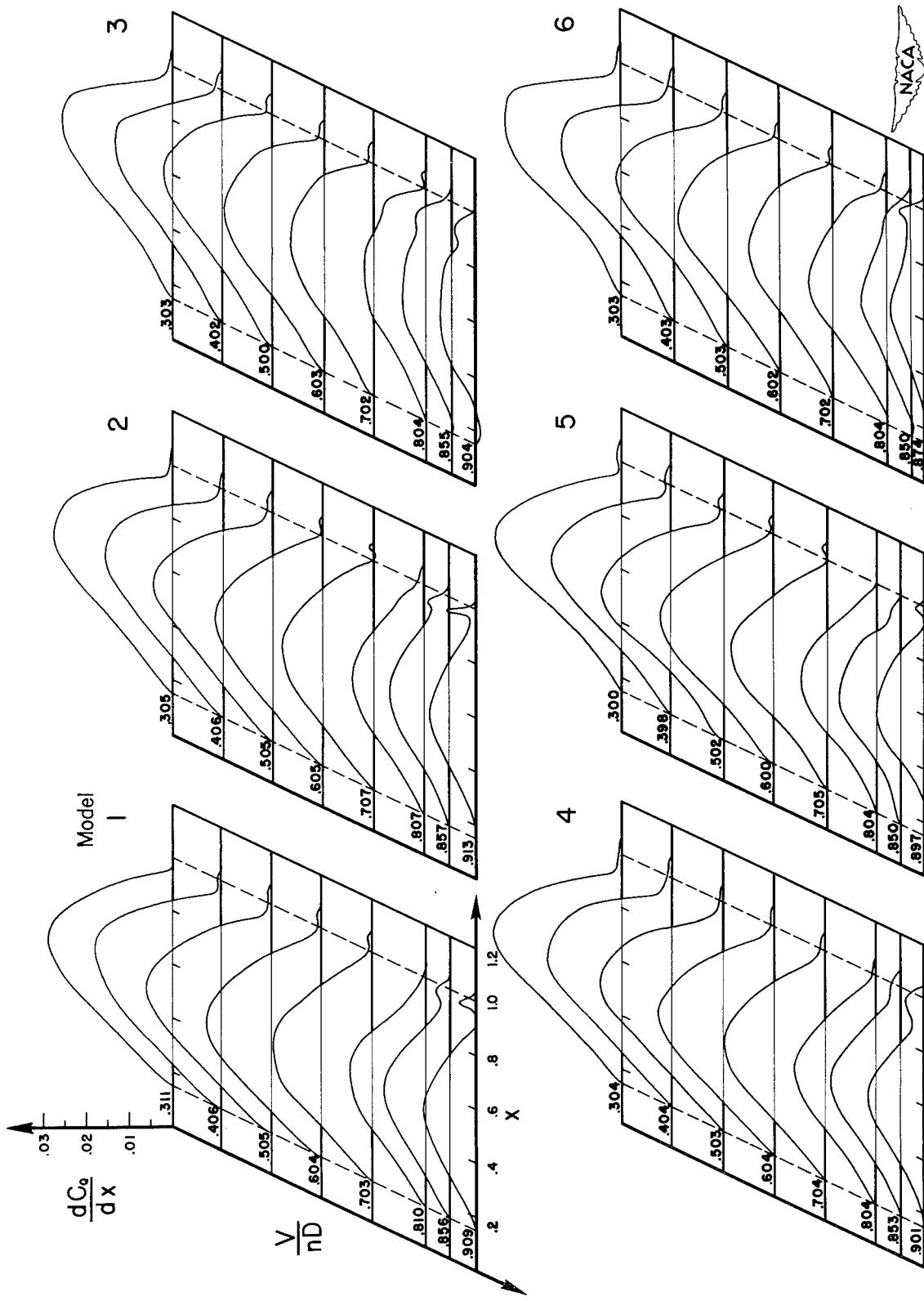


Figure 24. - Torque grading curves.  $\beta 0.75R = 19^\circ$ .

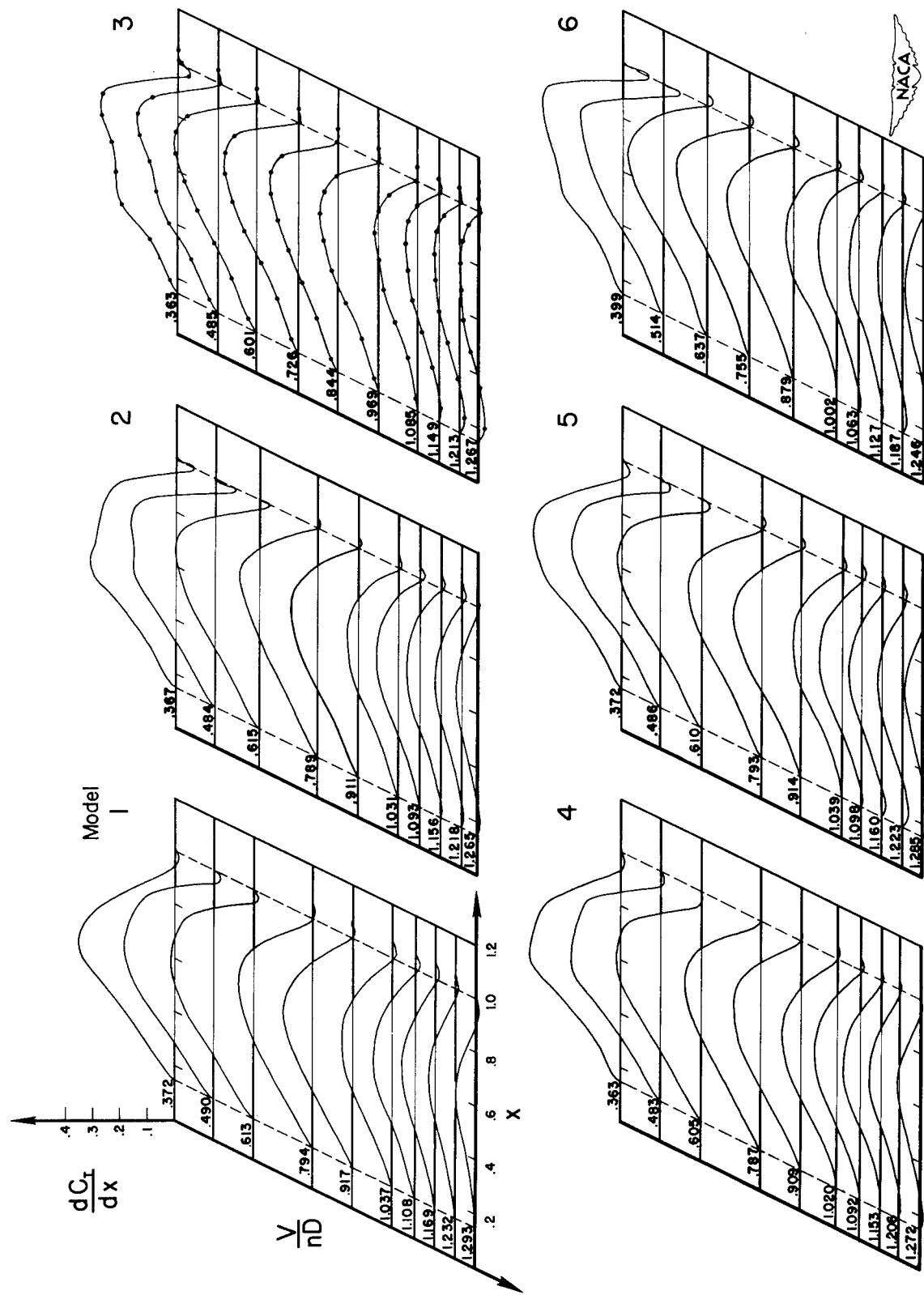


Figure 25. - Thrust grading curves.  $\beta = 27^\circ$ .

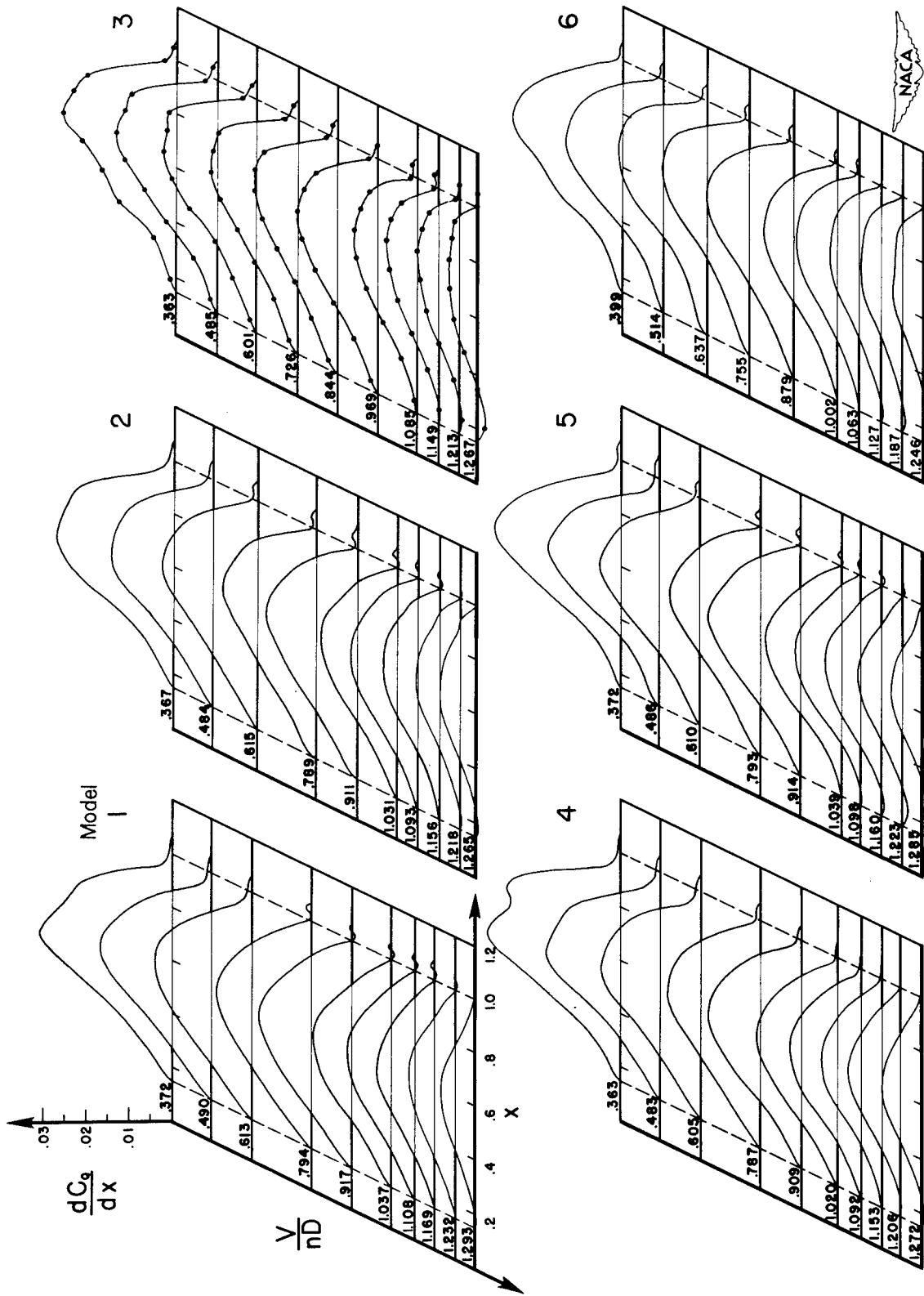


Figure 26. - Torque grading curves:  $\beta = 0.75R = 27^\circ$ .

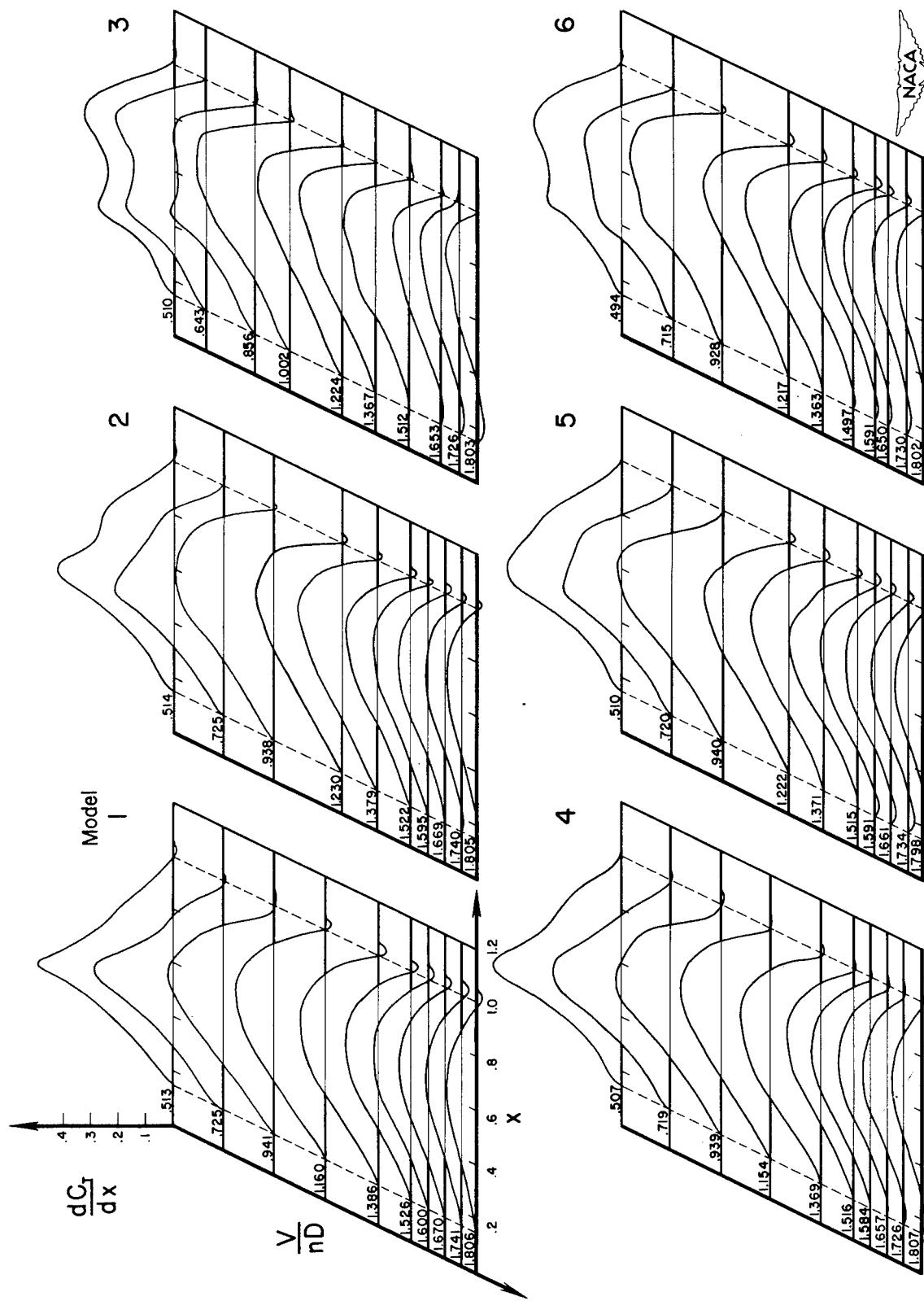
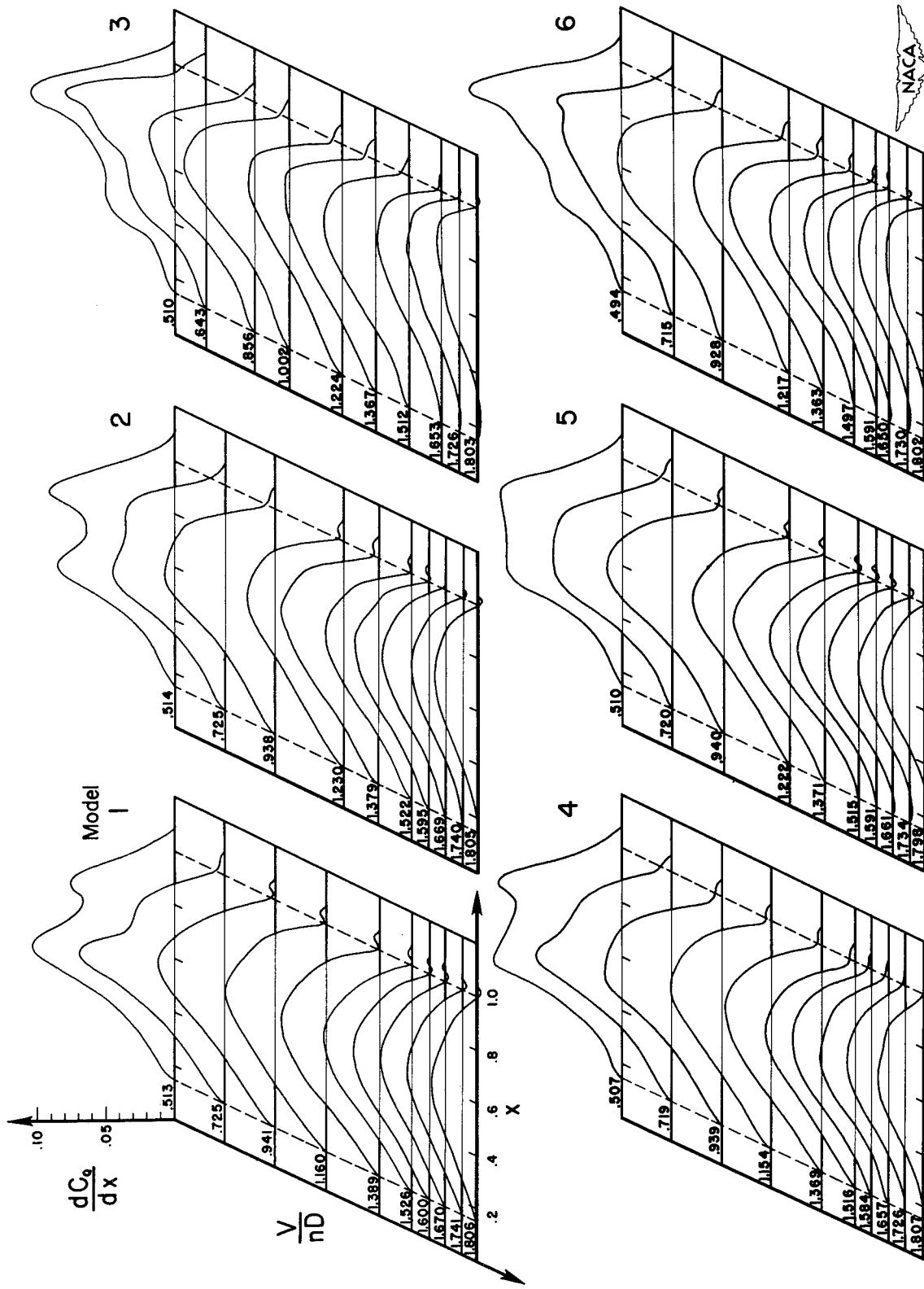


Figure 27. - Thrust grading curves.  $\beta = 0.75R = 37^\circ$ .

Figure 28. - Torque grading curves.  $\beta_{0.75R} = 37^\circ$ .

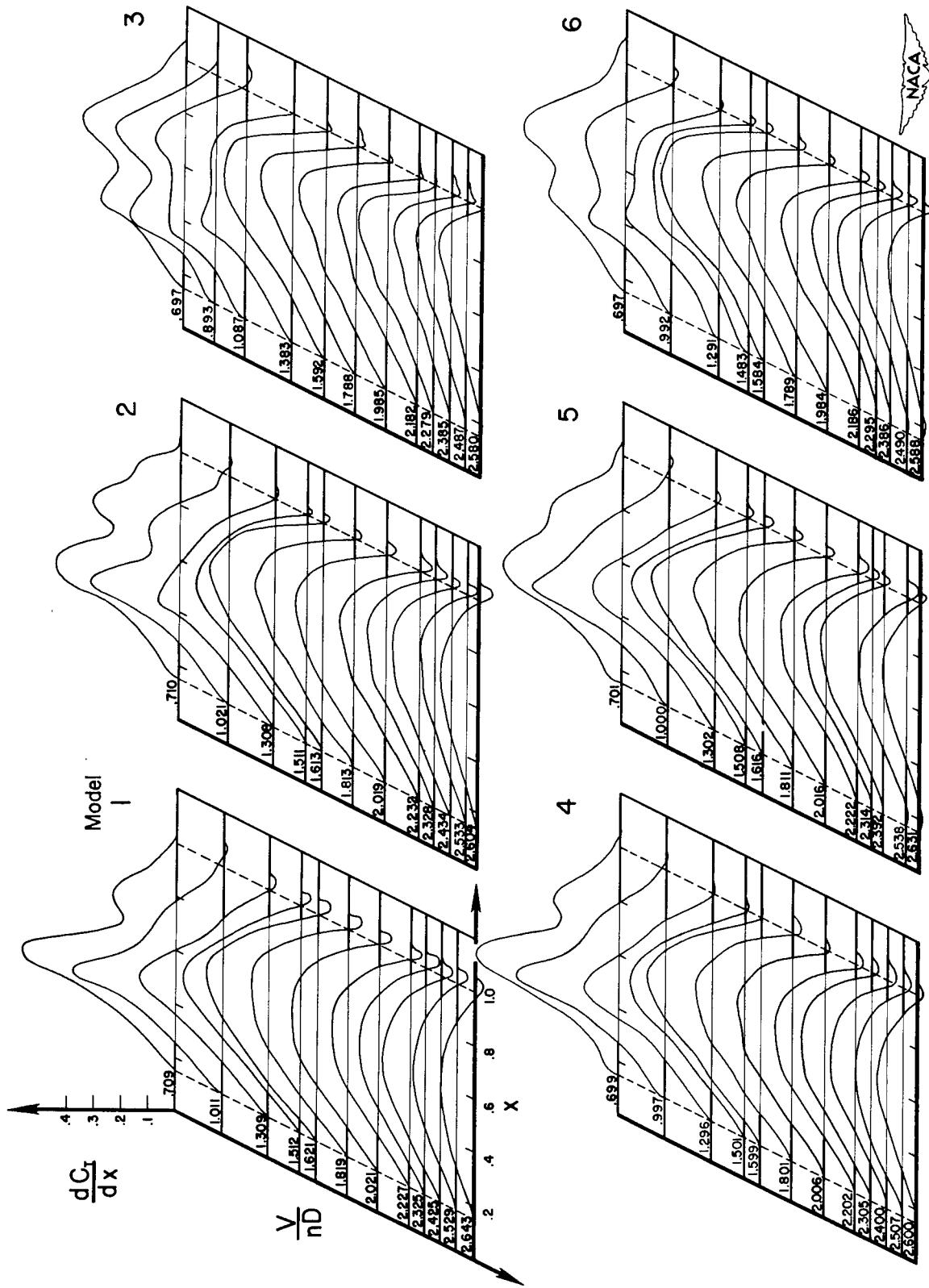


Figure 29.— Thrust grading curves.  $\beta_0.75R = 48^\circ$ .

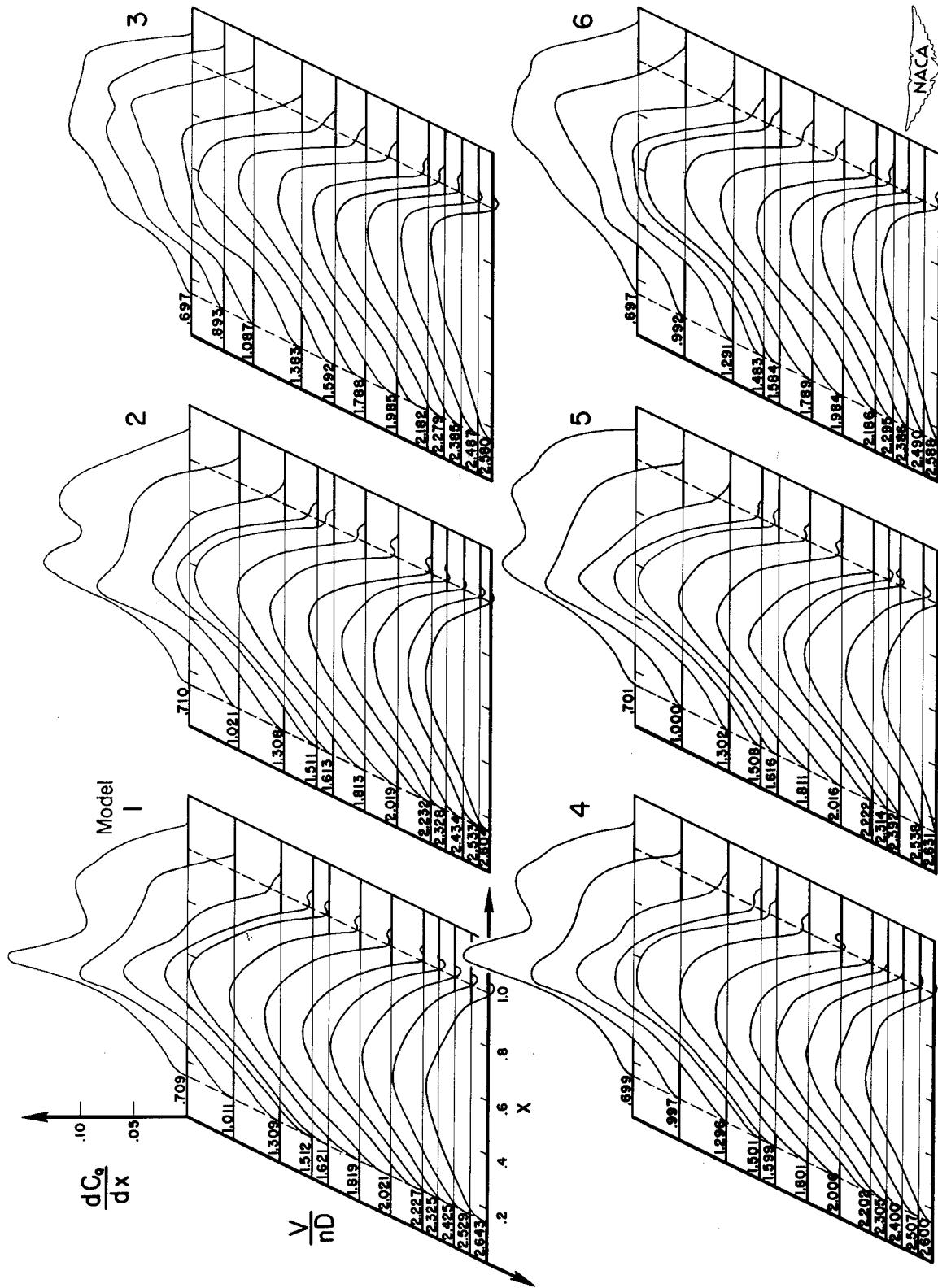


Figure 30.— Torque grading curves.  $\beta_0.75R = 480$ .

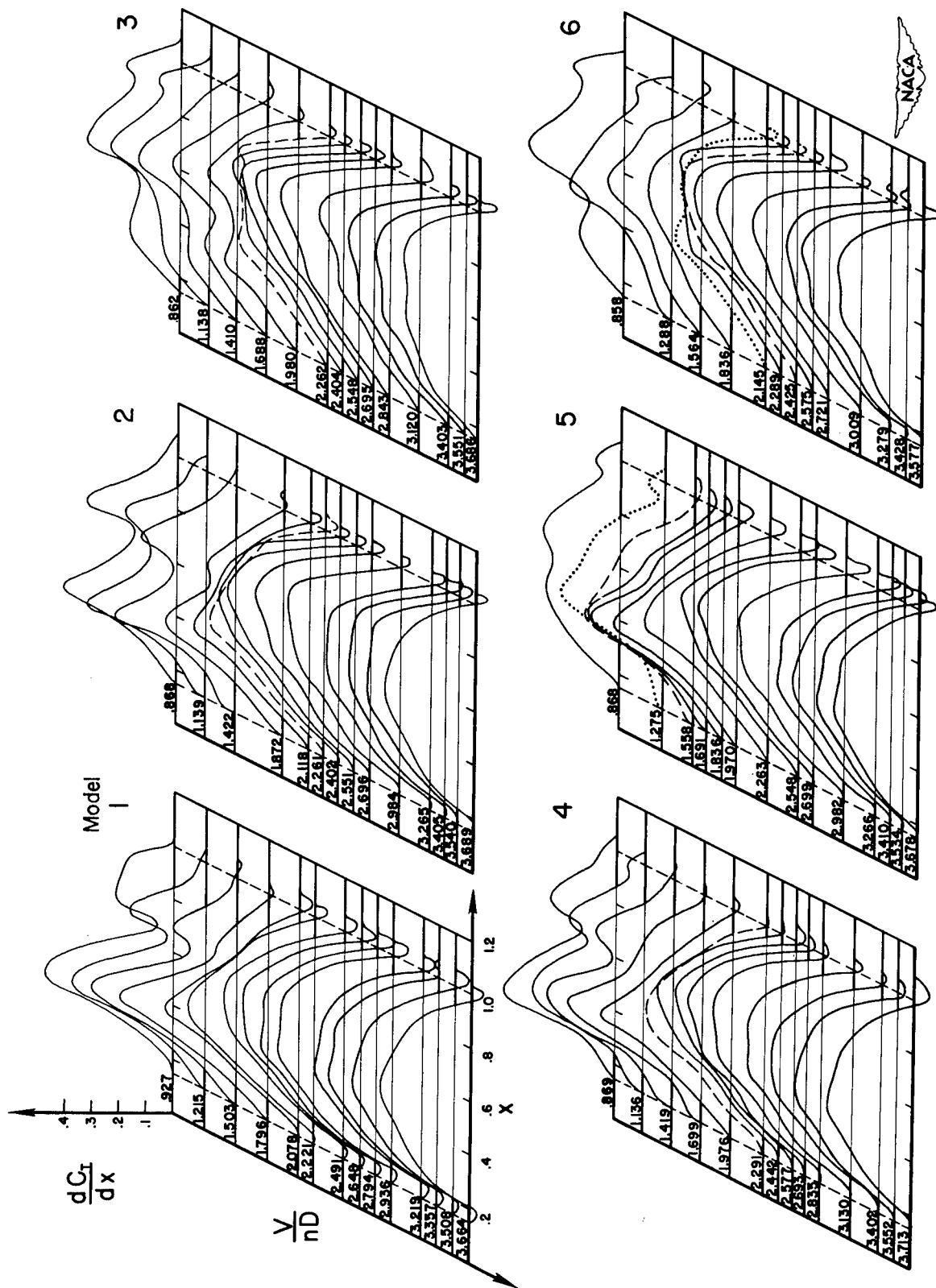


Figure 31.- Thrust grading curves.  $\beta = 60^\circ$ .

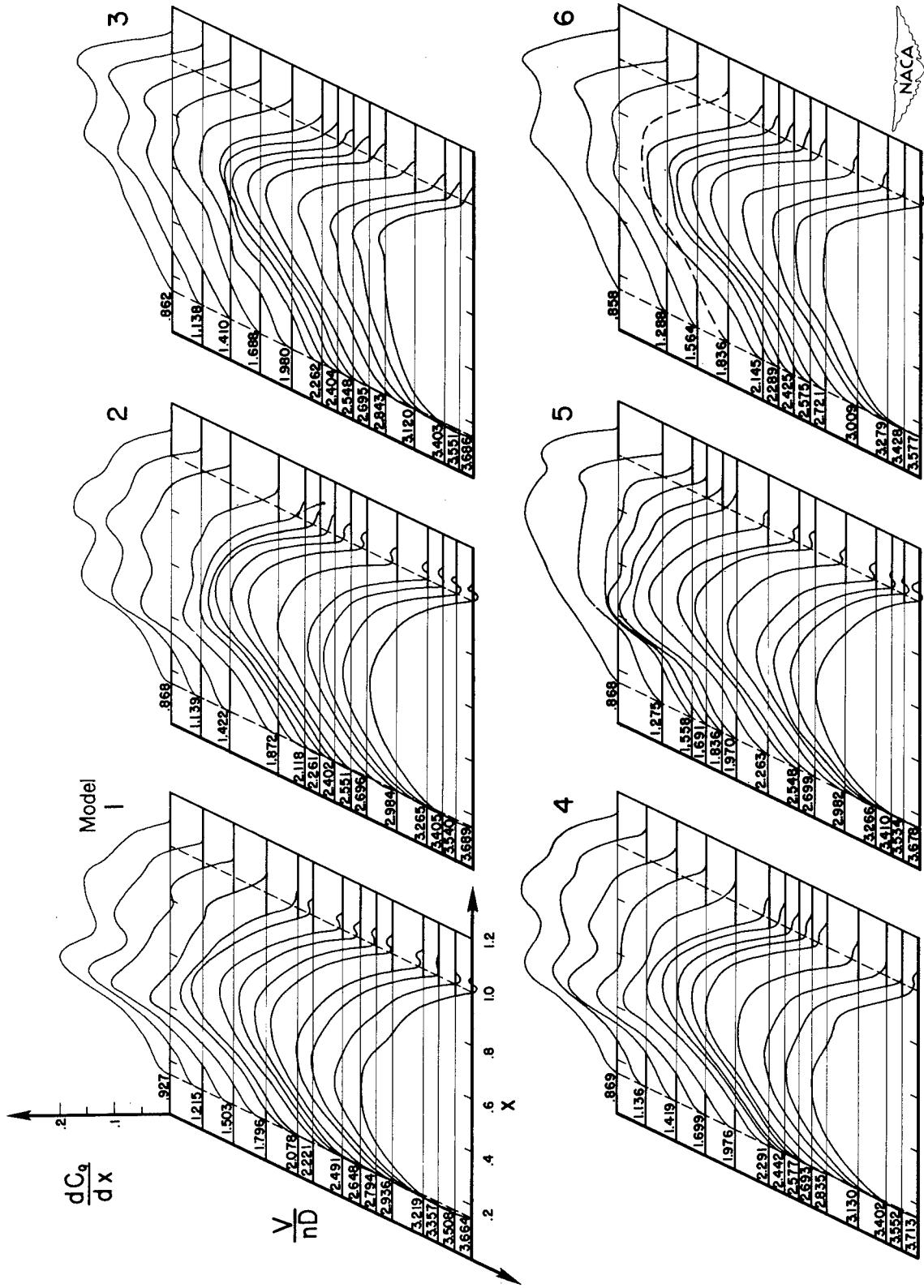


Figure 32.- Torque grading curves.  $\beta_{0.75R} = 60^\circ$ .

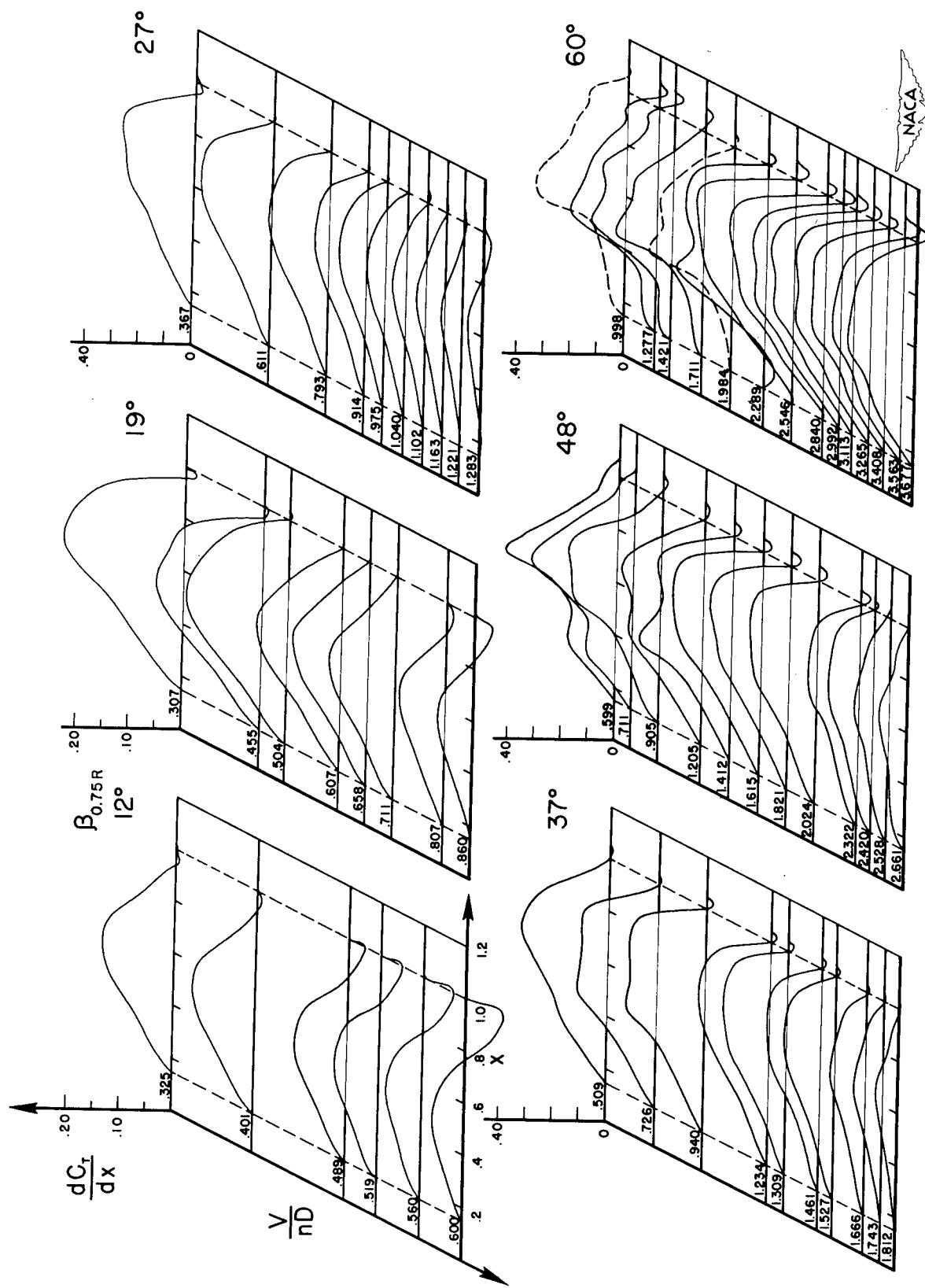


Figure 33.— Thrust grading curves. Model 7.

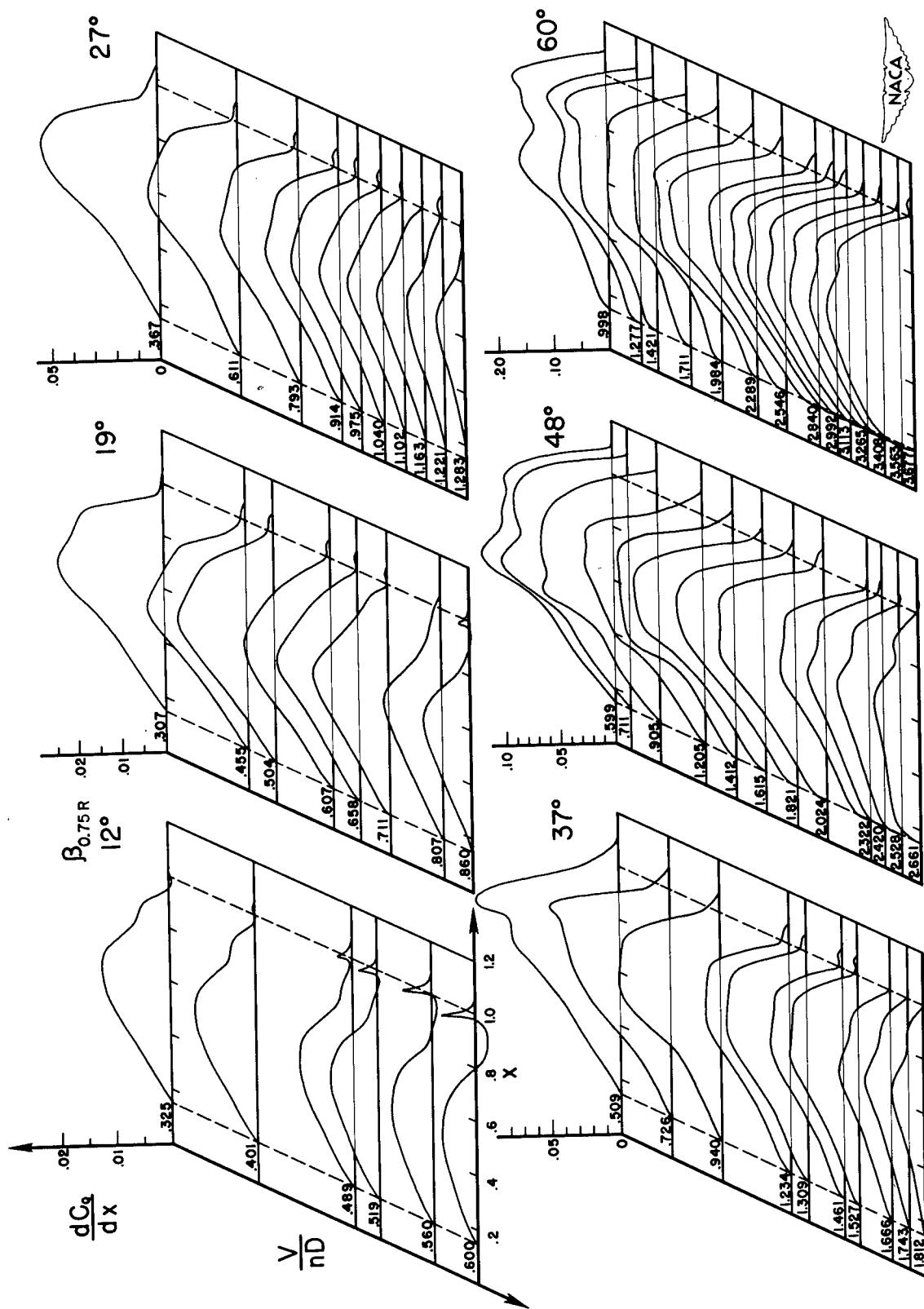


Figure 34. - Torque grading curves. Model 7.

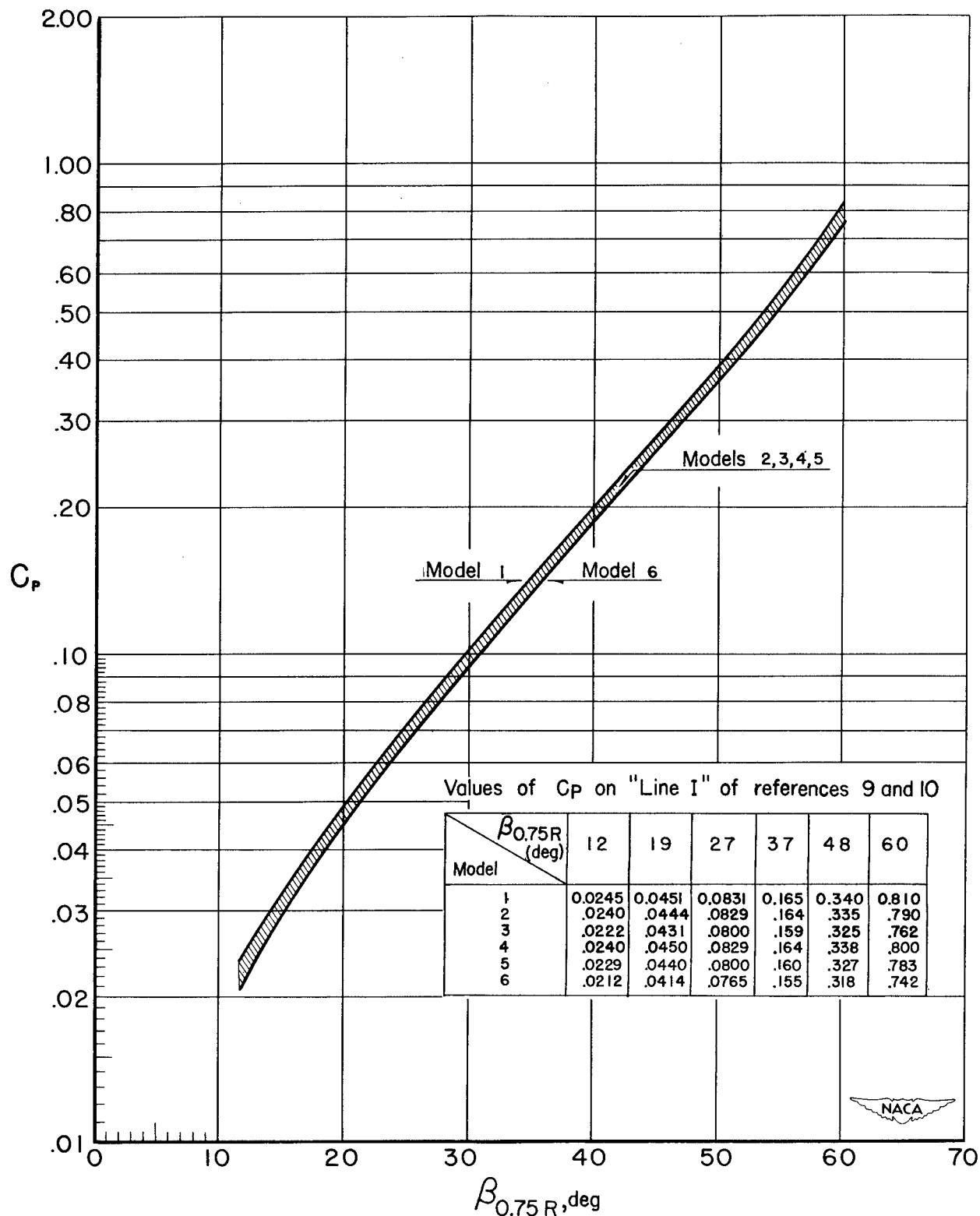


Figure 35.- Power absorbed by models 1 to 6.

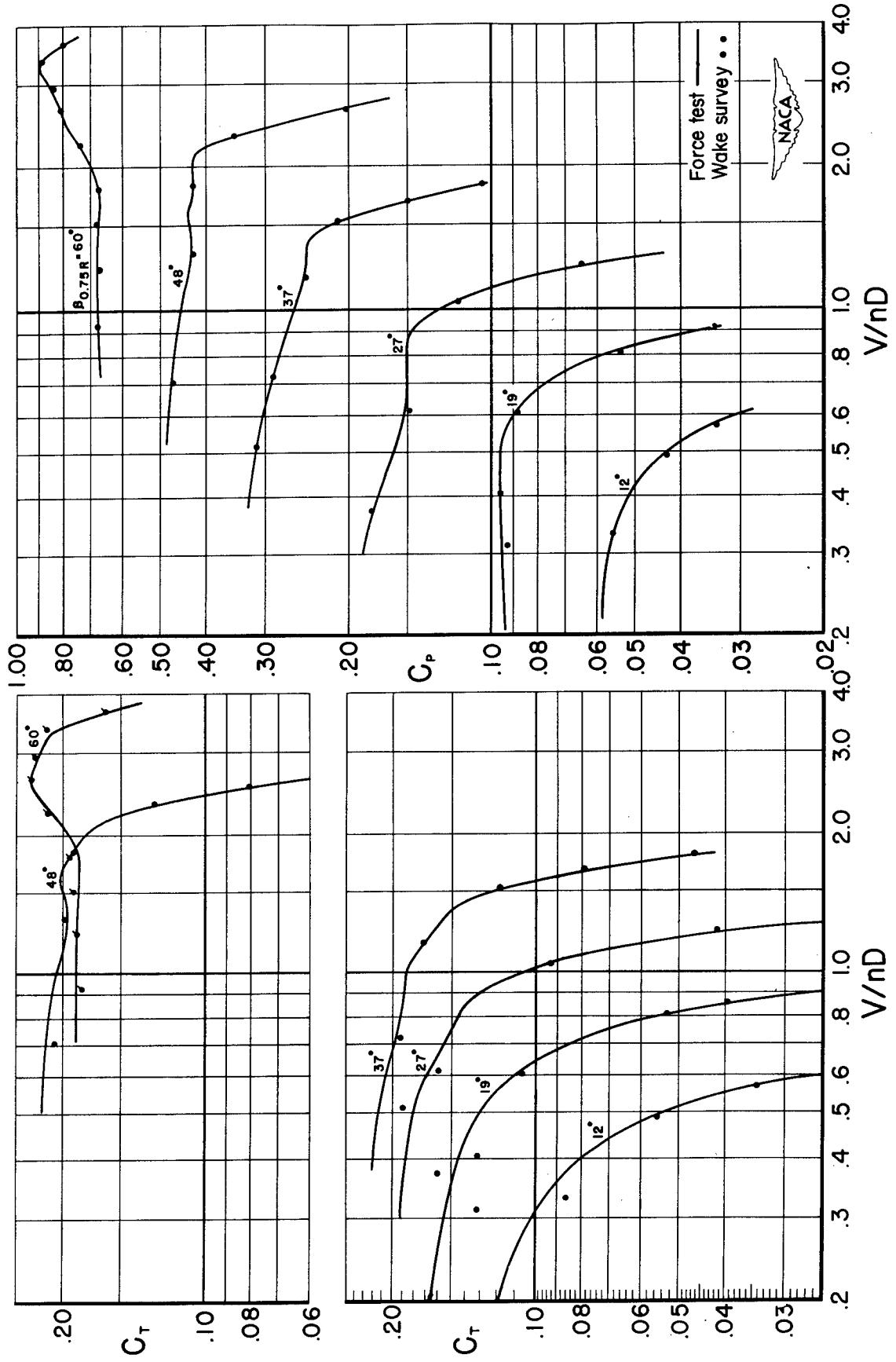


Figure 36.— Results of wake surveys and force tests. Model 1.

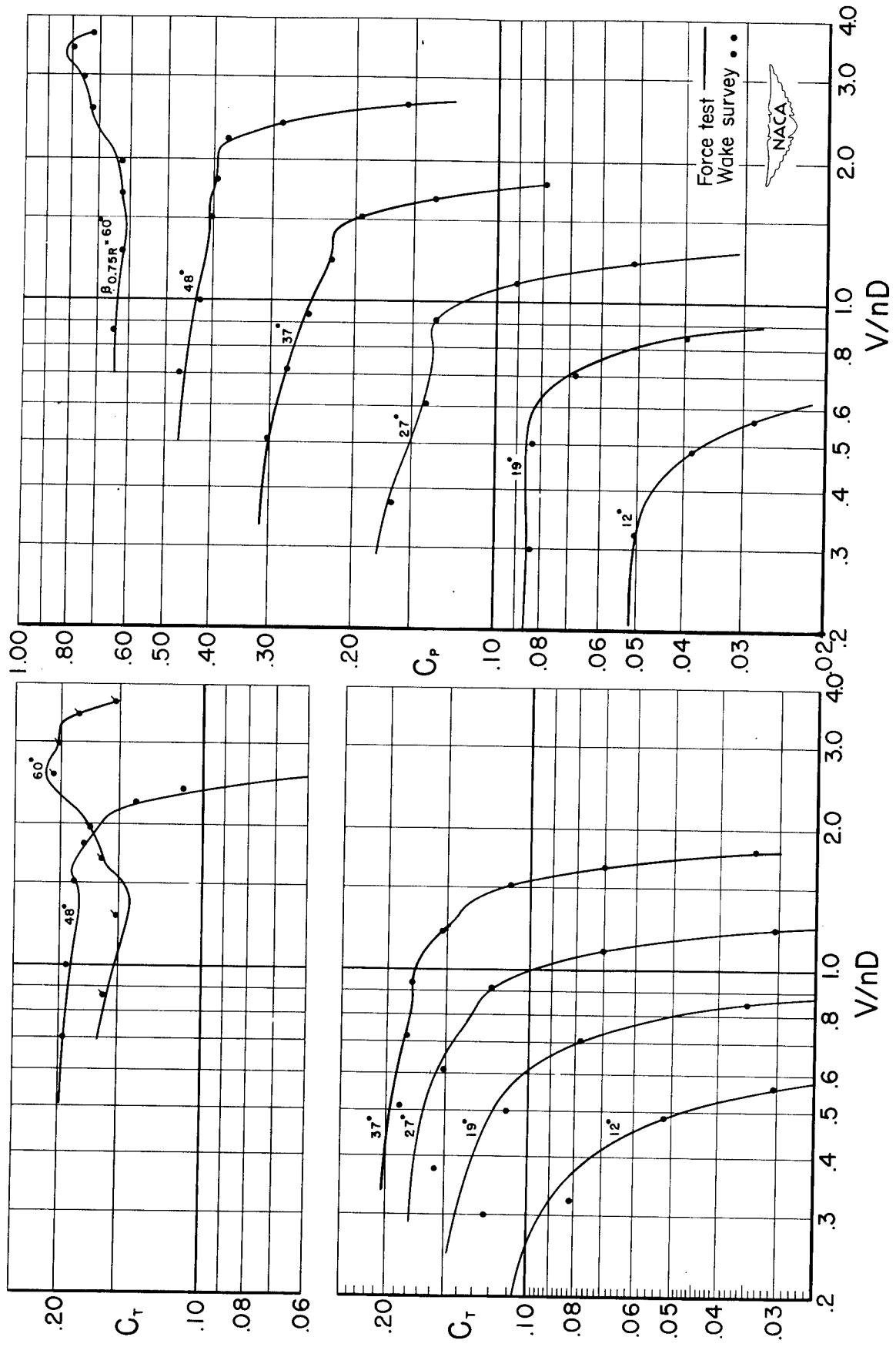


Figure 37.— Results of wake surveys and force tests. Model 5.

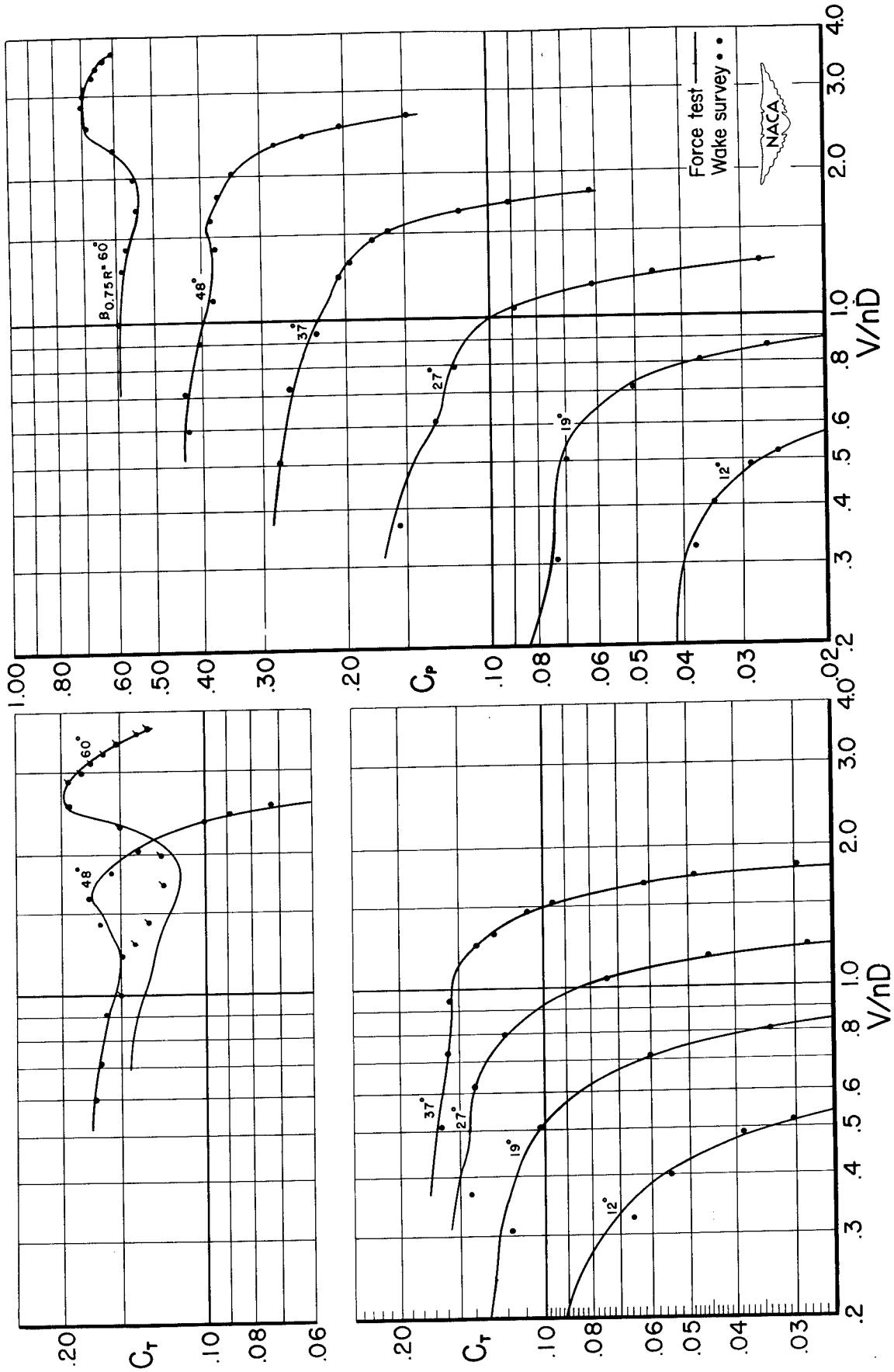


Figure 38.— Results of wake surveys and force tests. Model 7.

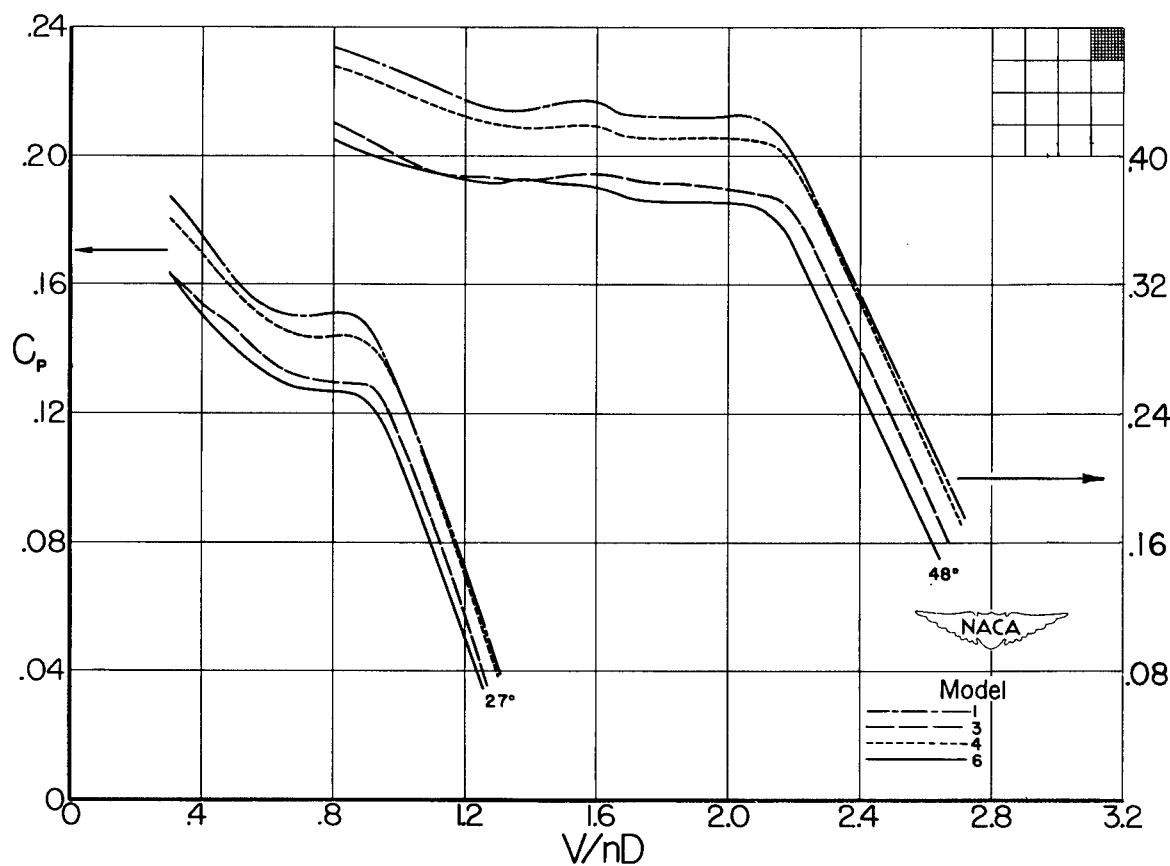
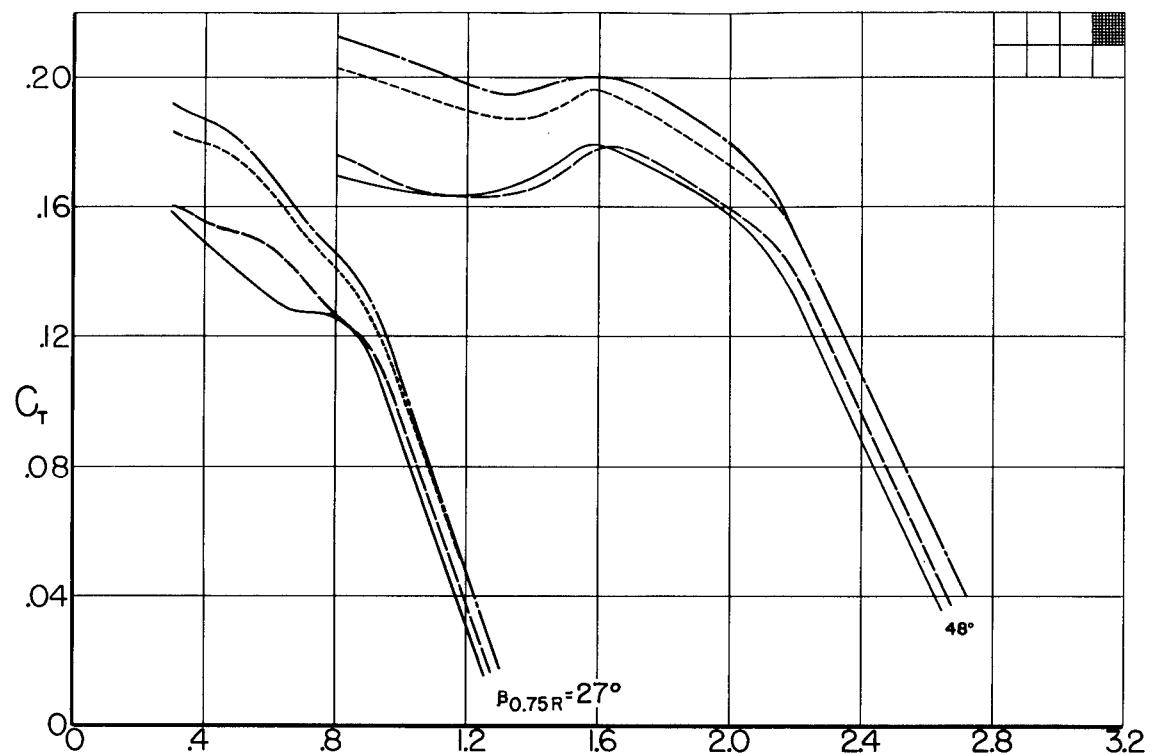


Figure 39.- Characteristic curves. Cartesian coordinates.

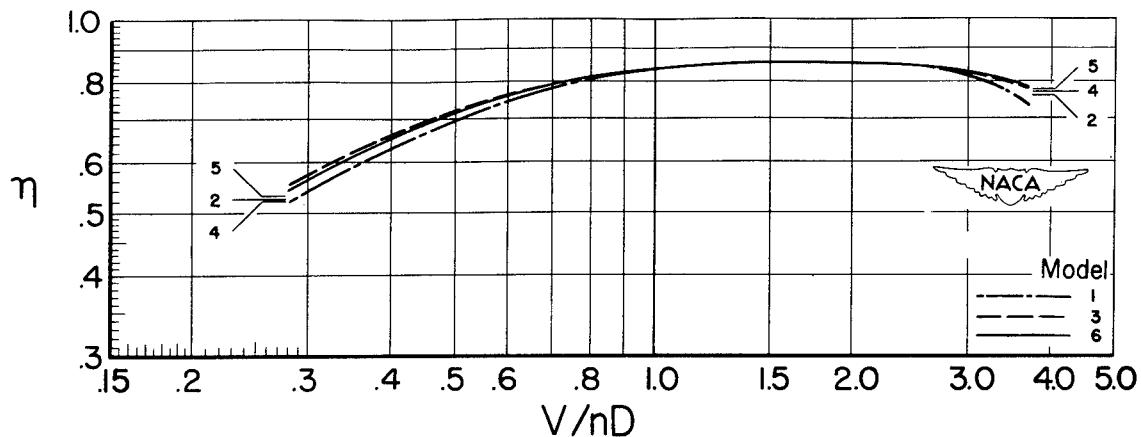


Figure 40.- Efficiency envelopes.

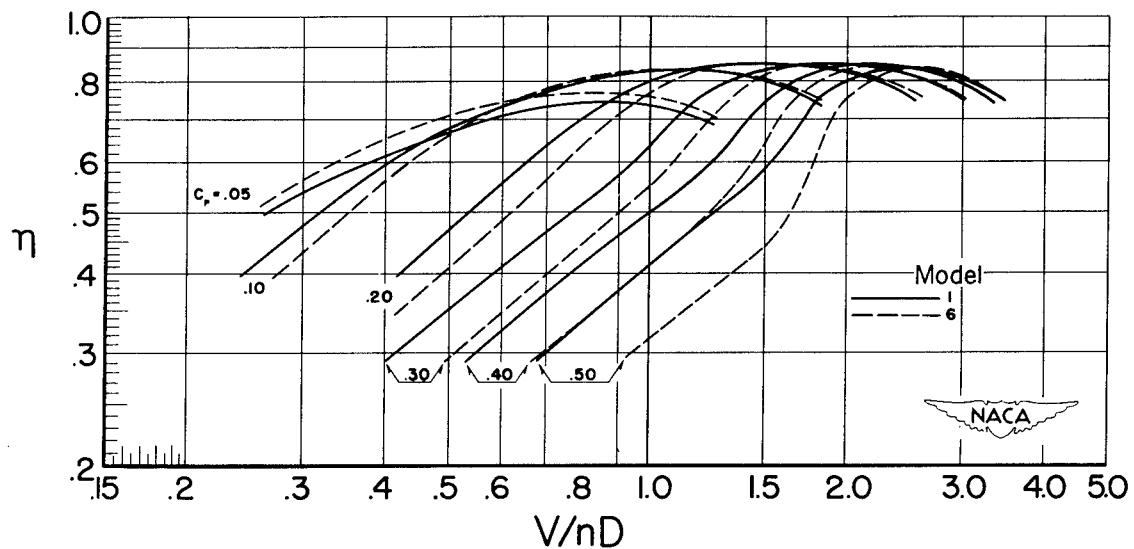


Figure 41.- Constant-speed efficiency curves. Model 1.

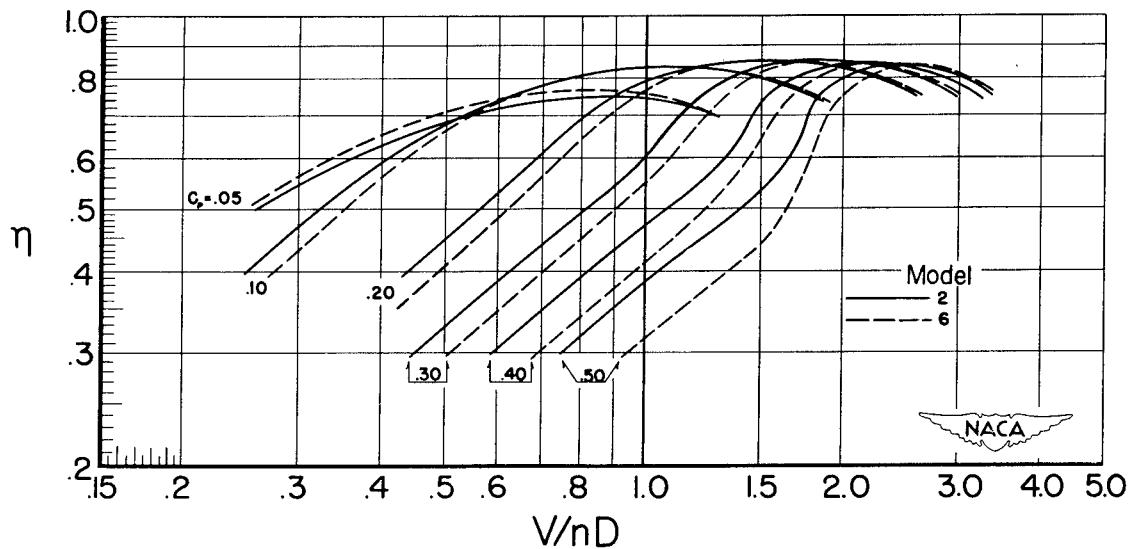


Figure 42.- Constant-speed efficiency curves. Model 2.

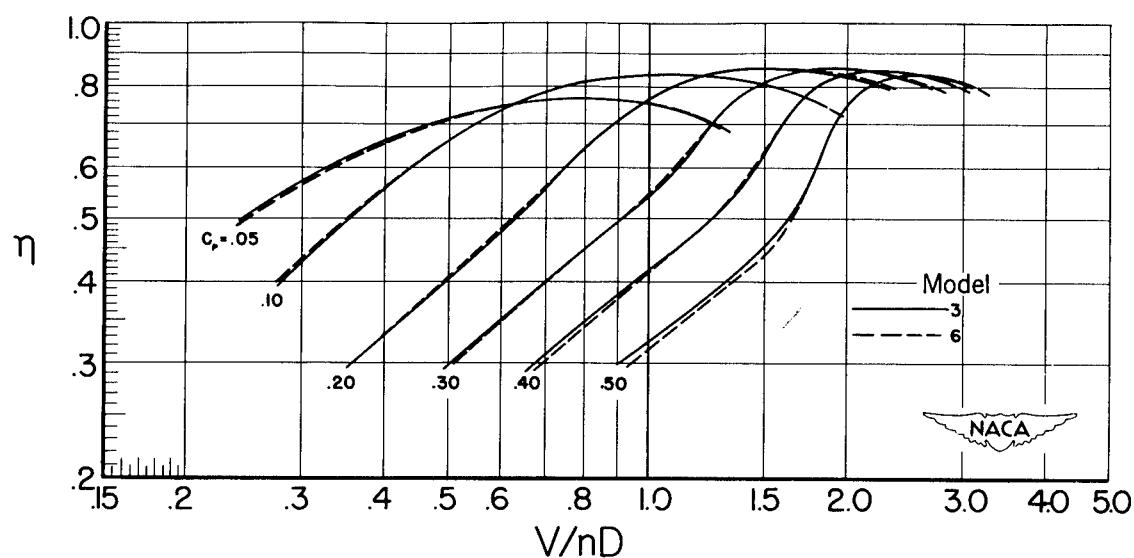


Figure 43.- Constant-speed efficiency curves. Model 3.

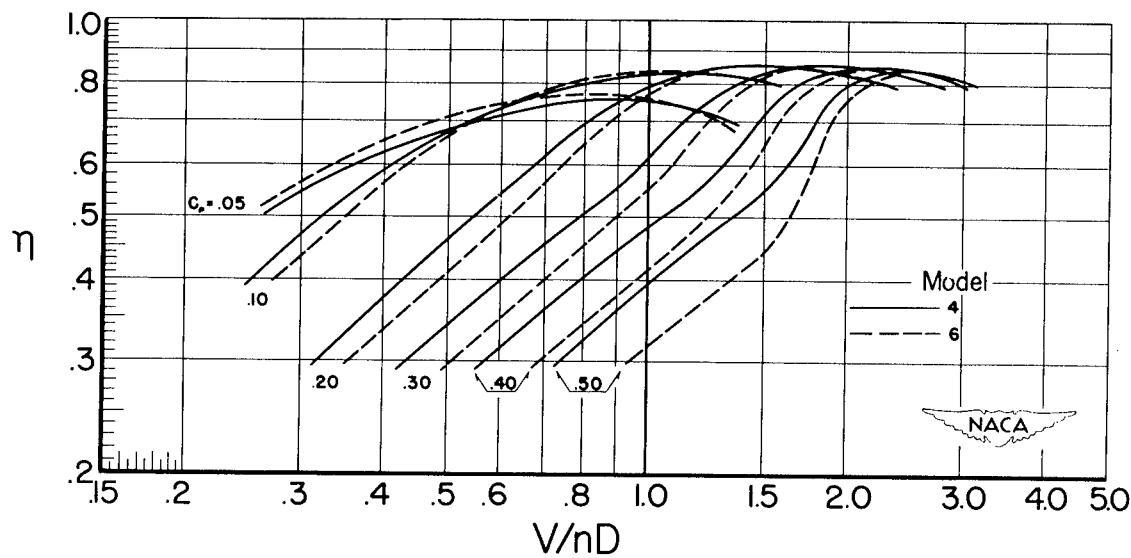


Figure 44.- Constant-speed efficiency curves. Model 4.

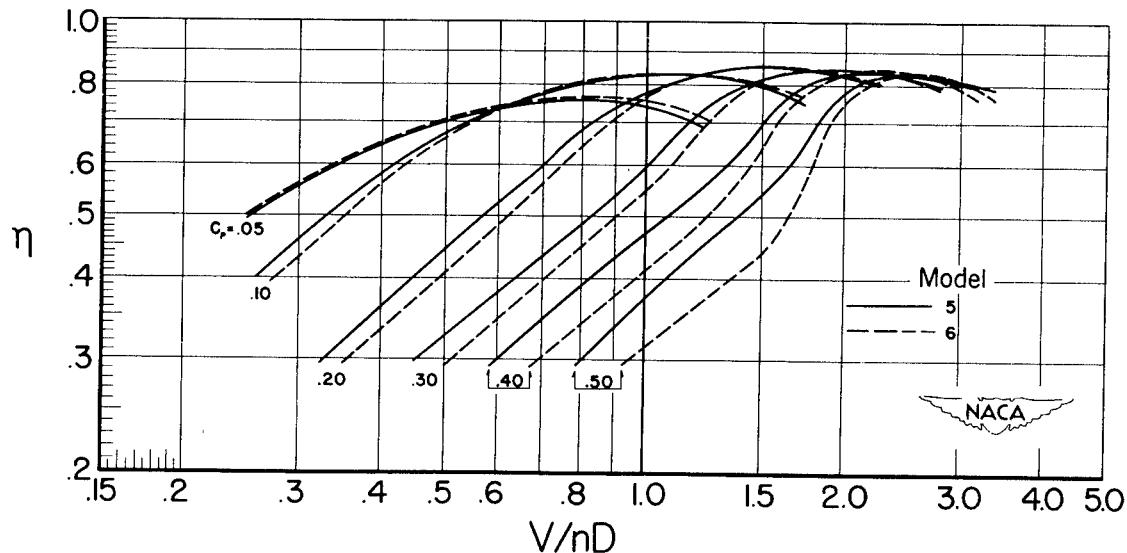


Figure 45.- Constant-speed efficiency curves. Model 5.

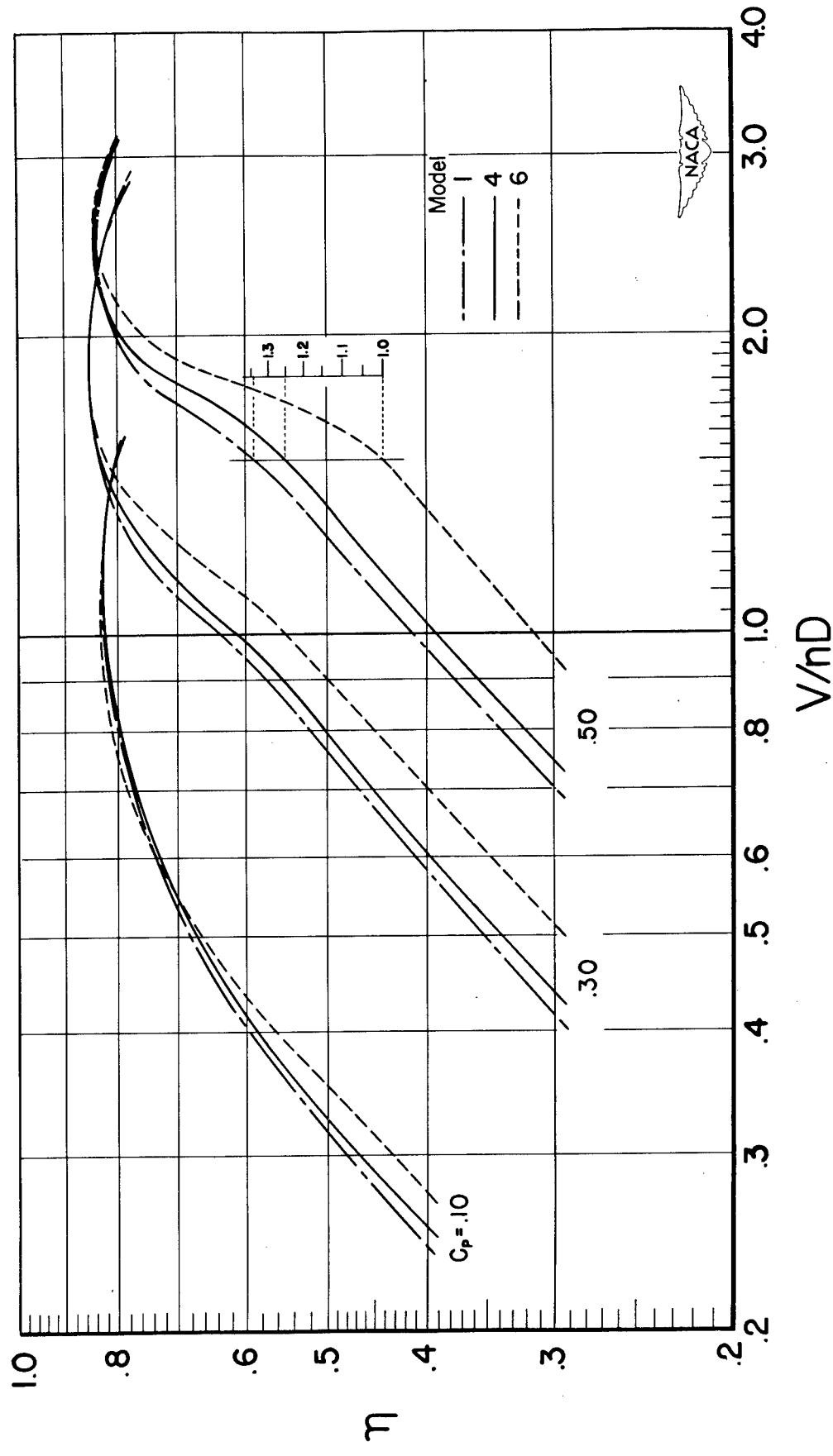


Figure 46. - Comparison of constant-speed efficiencies.

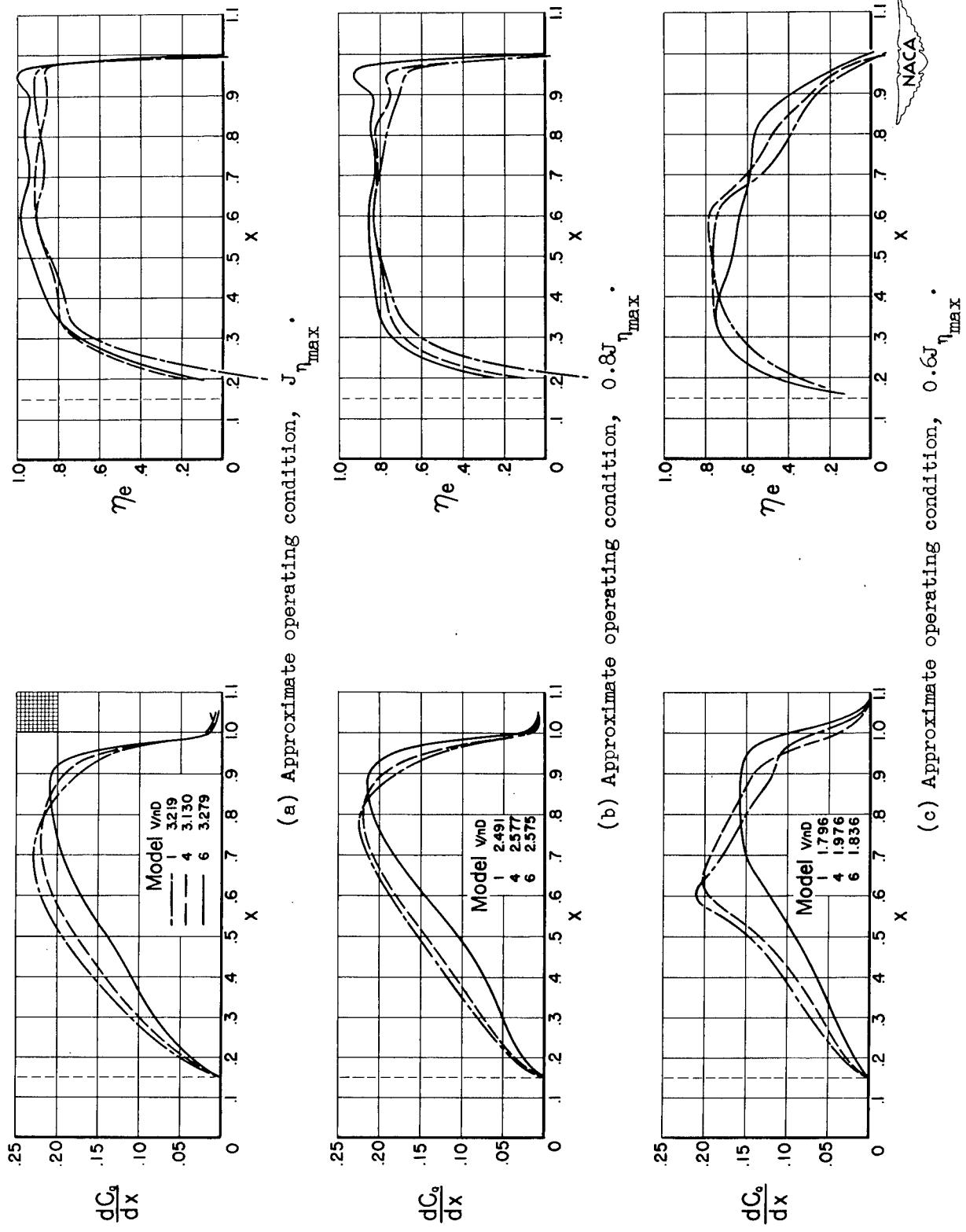


Figure 47. - Distributions of torque and efficiency.  $\beta 0.75R = 60^\circ$ .

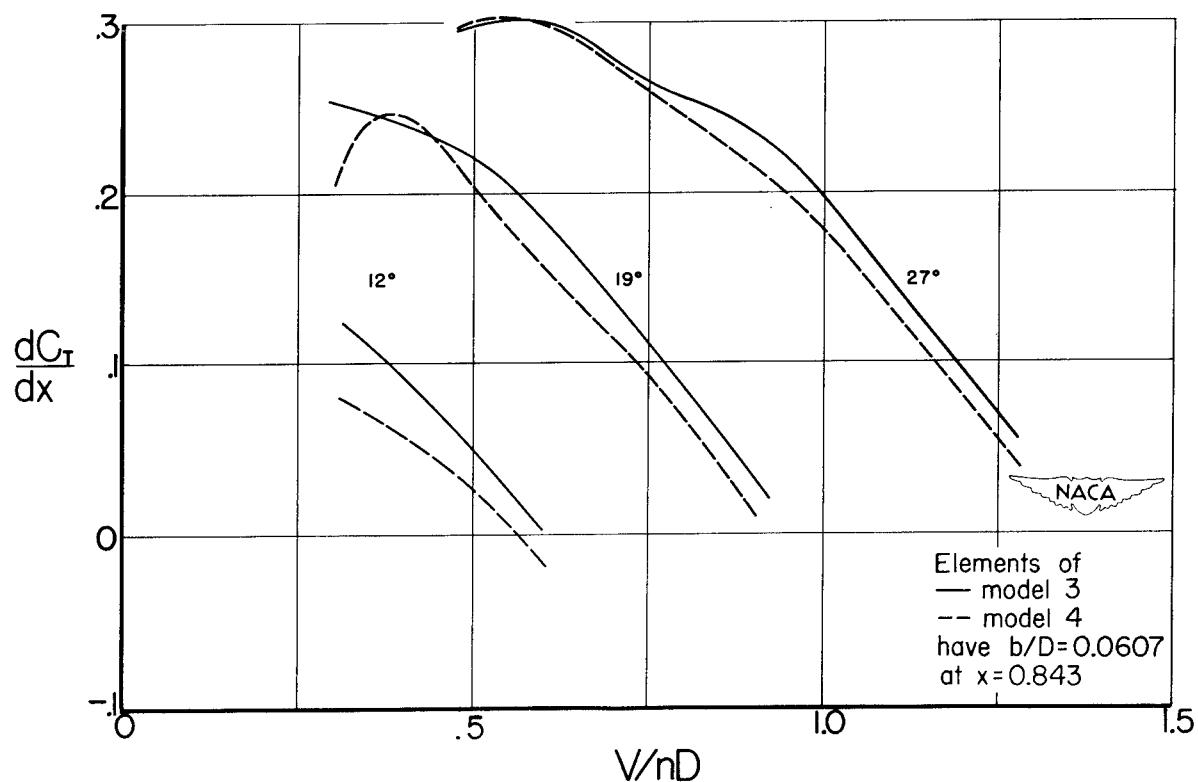
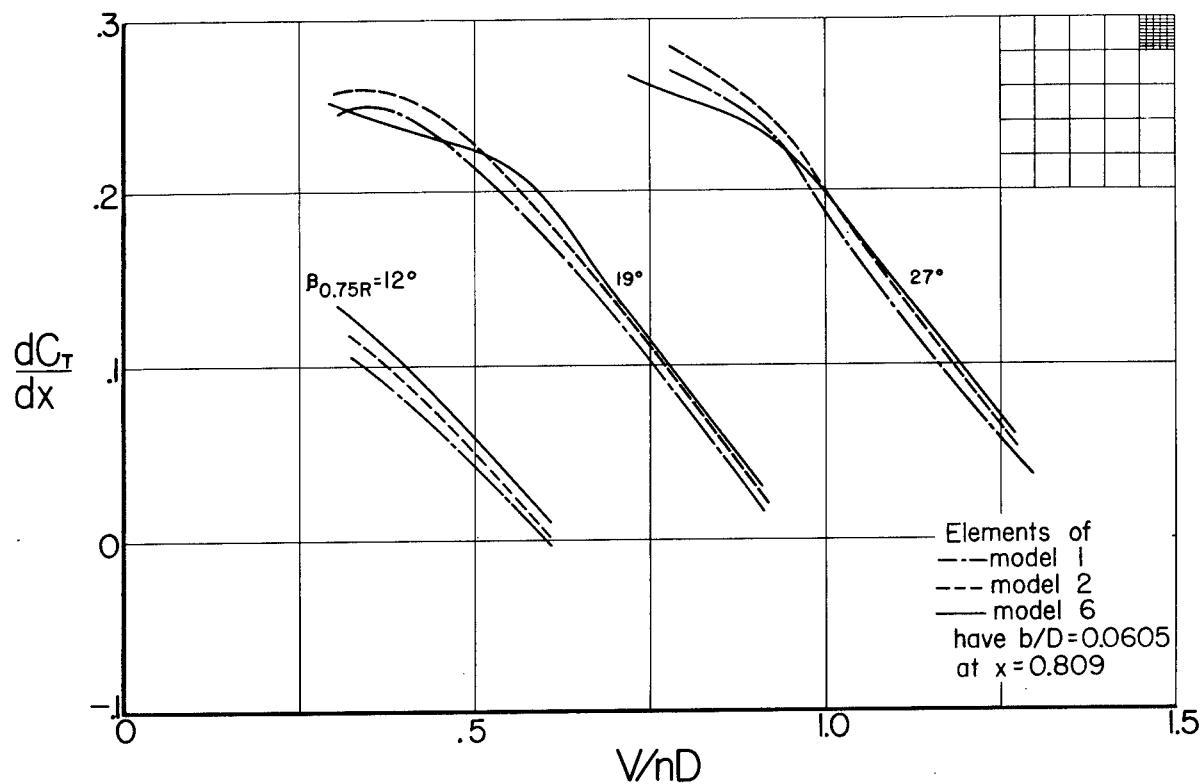


Figure 48.- Forces on corresponding elements of equal width.

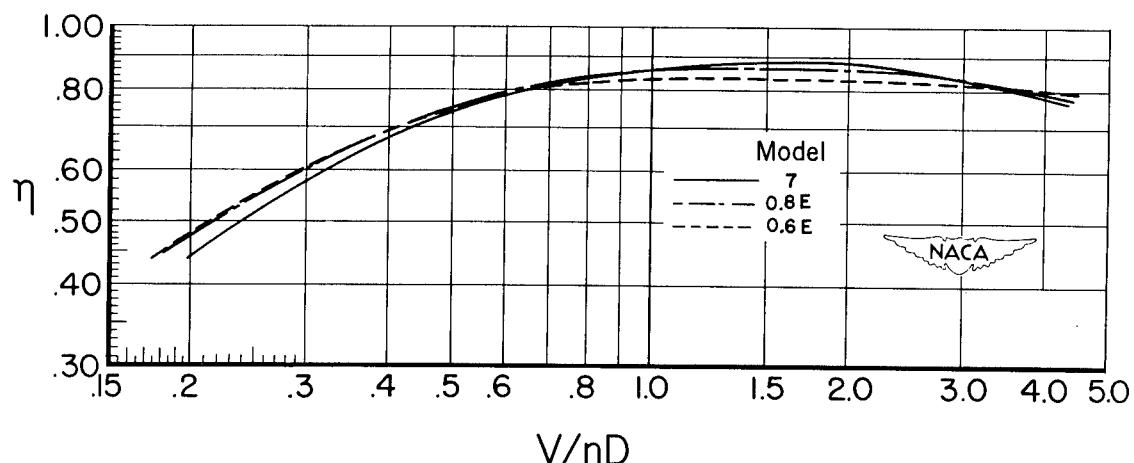


Figure 49.- Efficiency envelopes.

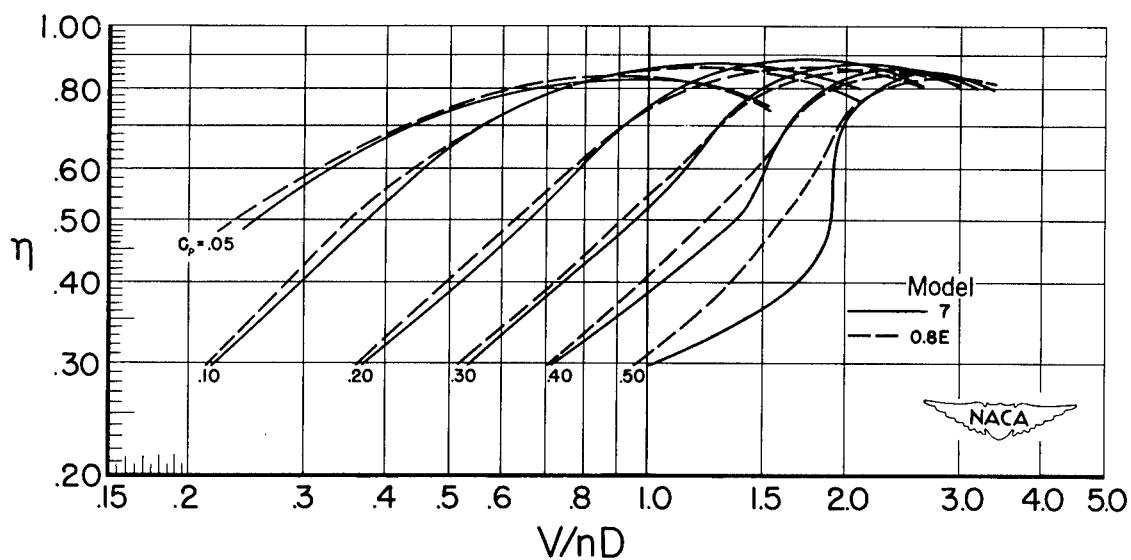


Figure 50.- Constant-speed efficiency curves. Models 7 and 0.8E.

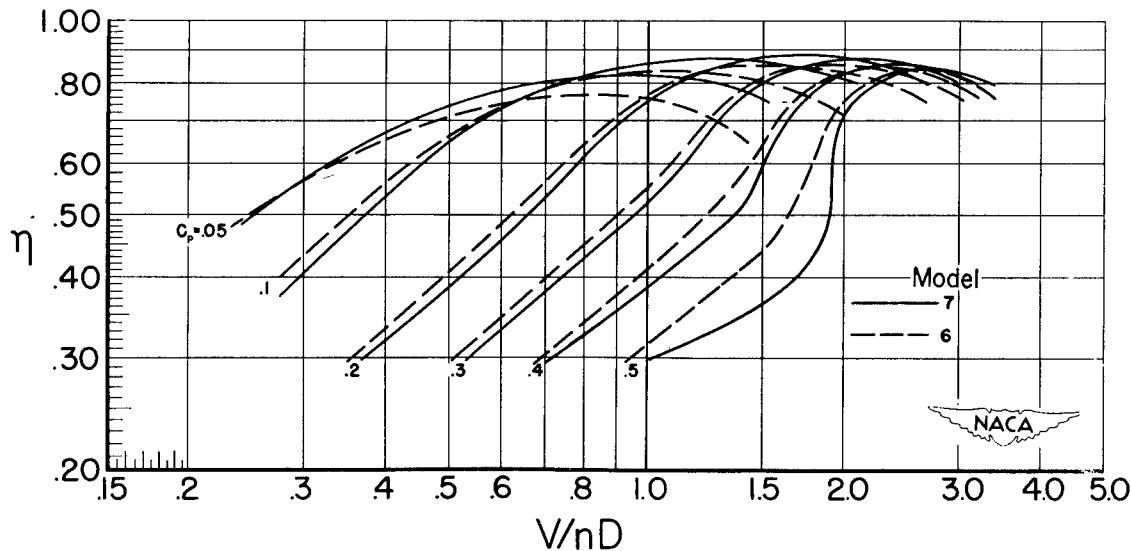


Figure 51.- Constant-speed efficiency curves. Models 7 and 6.

Solidity - Propellers

1.5.2.2



The Influence of Blade Width Distribution on  
Propeller Characteristics.

By Elliott G. Reid

NACA TN No. 1834  
March 1949

(Abstract on Reverse Side)



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**ABSTRACT:**

The influence of blade-width distribution on propeller characteristics was investigated by making force and wake survey tests on three-blade model propellers characterized by equal activity factors and dissimilar blade planforms. Although their efficiency envelopes differed inconsequentially, it was found that blades tapered from broad roots to narrow tips were more efficient than blades of relatively uniform width when operating at power coefficients greater than 0.1 and at advance ratios less than those for maximum efficiency. An explanation of the difference is deduced from wake survey data. Incidental results are evidence of nonindependence of blade elements and of the undesirability of highly cambered blade profiles.

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